



الملتقى العلمي الثالث والعشرون  
لأبحاث الحج والعمرة والزَّيَّارَة  
التميز الصَّحِّي في خدمة ضيوف الرحمن



جامعة أم القرى  
UMM AL-QURA UNIVERSITY

Under the generous patronage of  
The Custodian of the Two Holy Mosques

**King Salman bin Abdulaziz Al Saud**

May Allah protect him

**The scientific bulletin of**

**The 23<sup>rd</sup> Scientific Forum for Hajj, Umrah and Visit Research**

**Under the theme**

**Health excellence in serving pilgrims**



14-15 February 2024 ( 4-5 Shaaban 1445)



in Al Madinah Al Munawwarah,  
Le Meridien Medina

**Organized by**

**The Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research  
Umm Al-Qura University**

**The 23<sup>rd</sup> Scientific Forum  
for Hajj, Umrah and  
Madinah Visit Research**

**The Scientific Bulletin  
English Part**

## Preface

Under the generous patronage of the Custodian of the Two Holy Mosques King Salman bin Abdulaziz Al Saud (May Allah protect him), the Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research at Umm Al-Qura University organized the 23rd scientific forum for Hajj, Umrah and Visit Research under the theme “Health Excellence in Serving the pilgrims” in Al Madinah Al Munawwarah. It is worthy to be noted that this forum is held annually, once in Makkah, and once in Al Madinah Al Munawwarah. This forum is considered an annual scientific occasion and an opportunity in which specialists, officials, and workers in the field of Hajj, Umrah, and visit meet, to present a summary of their research, studies, and proposals, and to exchange viewpoints and benefit from the latest global technologies and scientific developments towards continuous development and progress in serving pilgrims, Umrah performers, and visitors, feeling This includes the importance and necessity of harnessing useful knowledge and good deeds in the service of the Two Holy Mosques.

The forum aims to recruit specialized researchers in Saudi Universities and research institutes, and those interested in Hajj, Umrah, and visit studies and their research, in addition to those working in government agencies, the private sector, and the third sector, to present their original scientific papers through the forum’s themes which are ; mass gathering health and safety strategies in the Holy Places, preventive health and health promotion for pilgrims, technology transformations in healthcare for pilgrims, and environmental sustainability and the health of the pilgrims.

The Scientific Committee received about 206 research abstracts from more than 40 academics, governmental, private and third sector bodies. They were reviewed with the help of experts and specialists, and then 115 topics were selected, distributed in scientific and working papers. This scientific record contains 73 scientific papers, while the forum’s website contains scientific posters including the remaining work papers.

On this occasion, the Scientific Committee of the Forum extends its sincere thanks to the researchers who presented to the Forum a summary of their work and ideas and to the specialized arbitrators from health colleges of Umm Al-Qura University and those with experience at the Institute who evaluated and reviewed the submitted research work and helped the Scientific Committee to make decisions to accept the qualified scientific contributions.

The Scientific Committee also extends its sincere thanks to everyone who contributed to providing scientific, material and moral support, in particular His Excellency the Minister of Education, His Excellency the President of Umm Al-Qura University, and the Dean of the Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research who is Chairman of the Forum’s Organizing Committee.

**Scientific Committee of the 23<sup>rd</sup> Scientific Forum of Hajj,  
Umrah and Madinah Visit Research**

## The Scientific Committee of the 23<sup>rd</sup> Scientific Forum of Hajj, Umrah and Madinah Visit Research

The Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research – Umm Al-Qura University

14-15 February 2024 / 4-5 Shaaban 1445H

Email: [multaqa@uqu.edu.sa](mailto:multaqa@uqu.edu.sa)

Website: <https://hajj.uqu.edu.sa/multaqa/22>

P.O. Box: 6287- Postal Code: 21955 Makkah Al-Mukaramah

## The main scientific committee of the 23<sup>rd</sup> Scientific Forum for Hajj, Umrah and Visit Research

### Chairman of the Committee

Dr. Amer A. Alzaidi

### Committee members

Dr. Adnan Y. Alshahrani

Dr. Emad A. Aljahdaly

Dr. Fatima J. Alsolami

Dr. Ali M. Alshehri

Dr. Radi T. Alsafi

Dr. Omiama H. Abdullah

Dr. Mashael S. Algahtani

Dr. Abdullah A. Bagasi

Dr. Magid A. Bamaga

Dr. Majed A. Bawazeer

Dr. Mona E. Alharbi

Razaz H. Gabani

The scientific committee emanating from the main committee of the 23<sup>rd</sup> Scientific Forum for Hajj,

Umrah and Visit Research

**Chairman of the Committee**

Dr. Magid A. Bamaga

**Committee members**

Prof. Atif H. Asghar

Prof. Turki M. Habeebullah

Prof. Fathy F. Shaaban

Prof. Omar B. Ahmed

Prof. Ayman M. Mostafa

Prof. Mohamed Shambour

Dr. Waleed A. Abou El Saoud

Dr. Ahmed M. Hilali

Dr. Essam A. Morsy

Mr. Ayman E. Behany

Mr. Naif M. Bashraf

## Key speakers at the sessions of the 23<sup>rd</sup> Scientific Forum for Hajj, Umrah and Visit Research

### 1<sup>st</sup> Session **Mass gathering health and safety strategies in the Holy Places**

<b>Key speaker</b>	<b>Dr. Mohammed Khalid Alabdulaali</b> Assistant Minister of Health
--------------------	--

He currently holds the position of Assistant Minister of Health, a member of the Board of Directors of the Saudi Red Crescent, and Chairman of the Board of Directors of the Medical Referral Center. He also previously held a number of positions, such as Assistant Undersecretary for Hospital Services, Director General of Health Affairs in the Jazan Region, Director of Health Affairs in Al-Ahsa, and CEO of King Fahd Hospital in Hofuf. He has over 20 years of healthcare management and leadership experience across various positions. He holds a Master of Science degree in Healthcare Management from the University of Alabama, Birmingham and several training programs such as: the Executive Coaching Program from the University of Michigan and the Senior Executive Education Program at the London Business School (LBS). A set of licensing certificates in the field of quality and health services management, and membership in the American College of Health Executives (ACHE). He is a member of the Advisory Committee of the College of Medicine at King Faisal University and has many peer-reviewed scientific papers and many scientific contributions in local and international conferences and forums.

### 2<sup>nd</sup> Session **Environmental sustainability and the health of the pilgrims**

<b>Key speaker</b>	<b>Dr. Sari Ibrahim Asiri</b> Director General of the Hajj and Umrah Department at the Ministry of Health
--------------------	--

He currently holds the position of Director General of the General Administration of Hajj and Umrah at the Ministry of Health. He also holds the position of Assistant Director General of Health Affairs for Public Health in the Makkah region. He is a member of the Healthcare Leadership Academy Innovation Program at Stanford University in the United States of America in 2020, as well as the Six Sigma Quality Training Program, and the Collaborative Corporate Training Initiative. He is also a certified trainer in the Family Medicine Fellowship, and participated as a lecturer and assistant in chronic disease programs. He also participated in primary health care programs and activities, emergency and disaster medicine programs during the Hajj seasons, and elderly care programs. He worked as an honorary assistant professor at Umm Al-Qura University in Makkah in 2019. He published many papers in prestigious international journals. Sari Asiri obtained a Bachelor's degree in Medicine and Surgery from Umm Al-Qura University in Makkah.

### 4<sup>th</sup> Session **Technology transformations in healthcare for pilgrims**

<b>Key speaker</b>	<b>Dr. Abdulaziz Suliman Alhomod</b> Deputy executive director of SEHA Virtual Hospital
--------------------	--

He currently serves as the Medical Director and Deputy CEO of Virtual Health Hospital, and is a Fellow of the prestigious American Medical Informatics Association and the American Academy of Emergency Medicine. He has extensive experience in the field of digital health, before joining SEHA Virtual Hospital. He is a consultant in emergency medicine at King Fahad Medical City since 2019. He obtained his bachelor's degree in medicine and surgery in 2008. He obtained a master's degree in biomedical informatics in 2020 from Oregon Health and Science University. He also collaborated with OCHIN – the non-profit Center for Healthcare Innovation – to improve diabetes care by leveraging EHR enablers. He has many scientific papers published in prestigious journals.

## Key speaker

**Dr. Mohammad Kamil Alharazi**

Executive Administration of Public Health and Preventive Medicine at Makkah healthcare cluster

An expert in preventive medicine and public health consultant in directing and streamlining comprehensive healthcare operations, he has the ability to assess the business situation, motivate employees, and drive change within organizations. He has a proven track record of providing professional advice, ensuring high quality, clinically safe, cost-effective medicine and improving health and wellbeing. Excellent in communicating with patients to implement safe work practices. And skills in aligning the goals of the units with the strategic goals of the hospitals. In identifying and solving complex problems for employees and patients to improve efficiency and excellence in implementing strategic goals and objectives, he also has the ability to maintain a safe environment for employees, patients, and visitors for organizational development.

## Table of Contents

<b>Preface</b> .....	<b>2</b>
<b>Theme of Mass Gathering Health and Safety Strategies in the Holy Places</b> .....	<b>9</b>
Enhancing Emergency Medical Response by Using Medical Drones in Makkah and the Holy Sites .....	10
Cognitive Forecasting of the Safety of Rahmani Crowds from the Perspective of Emergency Medical Services .....	18
Healthcare accessibility during Hajj 1444/2023.....	27
Pattern, frequency of dental and oral issues, and the patient’s satisfaction with the dental management and outcomes among pilgrims during the Umrah and Hajj.....	37
Innovative Approaches to Cardiac Care: Understanding the Significance of King Abdullah Medical City's Hajj Season Strategies on Door-to-Balloon Time for Primary Percutaneous Coronary Intervention.....	47
Effectiveness of Wearing Face Mask for Prevention of Respiratory Tract Infection During Hajj: A Systematic Review and Meta-Analysis .....	52
Vaccinations for Hajj: Enhancing Health and Global Health Security.....	66
Medical Convoy: Interfacility Transfer of Patients during Mass Gathering Event .....	79
Factors Influencing Prognosis of Myocardial Infarctions During Hajj Season .....	90
<b>Theme of Preventive Health and Health Promotion for Pilgrims</b> .....	<b>100</b>
Assessing the factors associated with food labeling knowledge for pilgrim's during Hajj period .....	101
A Survey of Using a Novel Mathematical Model (SEIRQ, SEIR) of COVID-19 Epidemic: On Analyze the Spread of Epidemics and Infectious Diseases in Saudi Arabia .....	111
Studying Dehydration Reduction Strategies During Hajj and Umrah Rituals: Behaviours used by the pilgrims and Barriers faced them .....	120
Nutritional knowledge among Hajj and Umrah service providers in the Kingdom of Saudi Arabia .....	127
Assessment of Carcinogenic Risks Associated with Trace Elements in Particulate Matter During the Hajj Season in Makkah: A Comprehensive Air Quality Study.....	138
Assessing the heatwaves trend in Makkah Province 1983 - 2016 using high-resolution (CHIRTS-daily) data.....	154
A Narrative Review on the Risk Factors Associated with Falls among Pilgrims during the Hajj and Umrah Seasons in Saudi Arabia .....	162
Integrating Physical Therapy in Health Service Provision During Hajj Season: A Literature Review.....	171
The Impact of a Prolonged 12-Hour Shift for Consecutive 15 Days on Occupational Fatigue, Missed Nursing Care and Quality of Nursing Care Among Nurses During Hajj: A longitudinal Study.....	185
Integrating Health Belief and Social Ecological Models: A Strategic Proposed Framework for Health Promotion and Education Among Makkah’s Pilgrims .....	190
Bibliometric Analysis of Health-Related Research on Hajj and Umrah in Saudi Arabia (1900-2023) .....	199
Optimizing Topical Formulations from Natural Sources for a Safe and Healthy Shaving Experience in Hajj .....	211
Nutritional Knowledge and Status Among Hajj Pilgrims and Umrah Visitors.....	221
A Healthier Hajj: Combating diseases and public health threats through preventive management. ....	232
<b>Theme of Technology Transformations in Healthcare for Pilgrims</b> .....	<b>244</b>
Clinical training and practice of using digital health solutions among healthcare workers in clinical centers during Hajj mission ...	245
Investigating the Opportunities and Challenges of Healthcare Process Mining (HPM) in Hajj and Umrah .....	252
Implementing Achievement Challenges Strategy at the Hajj to Enhance User Experience: A Mobile App-Driven Digital Transformation Approach.....	262



Modeling and Simulation of an Integrated System for Providing Medical Services for Pilgrims and Umrah Visitors through Medical Centers and Telemedicine.....	276
Explainable Machine Learning for Predicting Foodborne Infections .....	288
Technological Transformations in Combating Medically Important Arthropods during the Hajj and Umrah Seasons .....	304
“Nafee Application”: Utilizing facial recognition technology to speed up hospital procedures when obtaining pilgrim visas .....	316
Address the Gap between Healthcare Services and Healthcare Receiver during Hajj and Umrah .....	323
A Review of Machine Learning Techniques to improve Hajj Healthcare .....	332
Measuring and Analyzing Stress and Strain of the Guests of Rahman during Hajj Rituals Using Advanced Technologies .....	346
Detection of Covid-19 Using Efficient Ensemble Learning with Convolutional Neural Network .....	358
<b>Theme of Environmental Sustainability and the Health of the Pilgrims .....</b>	<b>368</b>
From Pilgrimage to Sustainable Practice: Leveraging Artificial Intelligence for the Future of Hajj .....	369
Exploring the impact of bed spacing during hajj season on missed nursing care and nurses’ satisfaction (nurses’ experience) .....	380
Enhancing Pilgrim Sleep Quality During Hajj: Effects of Indoor Environment on Sleep Staging .....	390
The impact of Health Excellence on Business Sustainability in the Hajj and Umrah: an analytical study from the point of view of health sector clients in Saudi Arabia.....	398
Health Impacts of Air Pollution during a short-term event (Hajj).....	404



الملتقى العلمي الثالث والعشرون  
لأبحاث الحج والعمرة والزياره  
التميز الصحي في خدمة ضيوف الرحمن



جامعة أم القرى  
معهد خادم الحرمين الشريفين  
لأبحاث الحج والعمرة

## Theme of Mass Gathering Health and Safety Strategies in the Holy Places



## Enhancing Emergency Medical Response by Using Medical Drones in Makkah and the Holy Sites

Fallatah Abbas Ahmed<sup>1\*</sup>, Eskander Howsawi<sup>2</sup>, Fallatah Mohammed Ahmed<sup>3</sup>, Aaidh Abdelaziz Mukhtar<sup>4</sup>

1- Retired Major from the Royal Saudi Air Force Air Force, 2- College of Engineering at Al Lith, Umm Al-Qura University, 3-Retired English language teacher, 4- Medical Laboratory Sciences Microbiology& Parasite.

\*Corresponding author: E-mail (absfalti88@gmail.com)

### تحسين استجابة الاطقم الطبية للحالات الحرجة باستخدام طائرات الدرونز في مكة والمشاعر المقدسة

عباس أحمد فلاتة<sup>1\*</sup>, د. إسكندر هوساوي<sup>2</sup>, محمد أحمد فلاتة<sup>3</sup>, عائض عبد العزيز مختار<sup>4</sup>

1- رائد متقاعد من القوات الجوية الملكية السعودية، 2- كلية الهندسة بالليث، جامعة أم القرى، 3- مدرس لغة انجليزية متقاعد، 4- متخصص علوم المختبرات الطبية الأحياء الدقيقة والطفيليات

#### الملخص

تماشياً مع رؤية السعودية 2030 لتقديم خدمات استثنائية للمواطنين والزوار تلي المعايير الدولية، تركز الحكومة السعودية على ضمان رفاهية الحجاج. ومن بين الأولويات القصوى في هذا الصدد الاستجابة الفعالة للحالات الطبية الحرجة وحالات الطوارئ. ولتحقيق مثل هذه الاستجابة، أنشأت الحكومة السعودية نظاماً طبيًا متطورًا. إحدى المشكلات المحددة التي تعيق الطوارئ الطبية هي الاستجابة في الوقت المناسب لحالة حرجة. خلال مواسم الذروة مثل الحج، يمثل نقل الإمدادات الطبية مثل أجهزة تنظيم ضربات القلب أو منتجات الدم إلى المواقع التي تشتد الحاجة إليها تحديًا كبيرًا بسبب التأخير الناجم عن الاختناقات المرورية أو الازدحام أو التضاريس الصعبة أو الازدحام الكبير للناس أو هطول الأمطار مما يجعل الطرق البرية غير مفيدة. يُظهر استخدام المركبات الجوية بدون طيار (UAVs) أو الطائرات بدون طيار نتائج واعدة لتحسين وقت الاستجابة في حالات الطوارئ. تتمتع الطائرات بدون طيار بالقدرة على التحليق وتخفيف العوائق المرتبطة بالطرق البرية. ولذلك، فإن استكشاف فوائد استخدام الطائرات بدون طيار لتعزيز الاستجابة لحالات الطوارئ الطبية يعد مهمة هامة. من خلال استخلاص الدروس من دراسات الحالة، ستعرض هذه الورقة فوائد استخدام الطائرات بدون طيار في الاستجابة لحالات الطوارئ الطبية وتقتراح إطارًا مختلفًا لأصحاب المصلحة لاعتماد استخدام الطائرات بدون طيار عمليًا.

الكلمات الدالة: الإمدادات الطبية، طائرات الدرونز، رعاية المرضى، الذكاء الاصطناعي، منتجات الدم.

#### Abstract:

In alignment with Saudi vision 2030 to provide exceptional services to citizens and visitors that meet international standards, the Saudi government focuses on ensuring the well-being of pilgrims. Among the top priorities in this regard is the effective response to critical medical situations and emergencies. To realize such a response, the Saudi government established a state-of-the-art medical system. One particular issue that hinders medical emergencies is the timely response to a critical situation. Transporting medical supplies such as defibrillators or blood products to locations where they are urgently needed is a significant challenge during peak seasons such as Hajj. This is due to the delay caused by

traffic jams, congestion, difficult terrain, high crowd of people or rainfall rendering land routes unusual. The use of unmanned aerial vehicles (UAVs) or drones shows promise to improve the response time in emergency situations. UAVs have the ability to overfly and mitigate the obstacles associated with land routes. Therefore, exploring the benefits of using UAVs to enhance medical emergency response is an important task. By extracting lessons from case studies, this paper will show the benefits of Using UAVs in medical emergency response and propose a framework for different stakeholders to practically adopt UAVs.

**Keywords:** medical supplies, drones, patient care, artificial intelligence, blood products.

## 1. Introduction:

Makkah and the Holy Places are of great importance in the context of emergency medical response (Leggio et al., 2016). As the spiritual center of Islam, millions of pilgrims from all over the world gather at these sites, especially during the annual Hajj season and throughout the year to perform Umrah. Due to the large number of pilgrims visiting Makkah and the Holy Places during Hajj and Umrah, medical teams face numerous challenges in providing timely and effective emergency care (Leggio et al., 2016). Transporting medical supplies, navigating dense crowds, and reaching patients in urgent need are particularly difficult (Shujaa & Alhamid, 2015) (Al-Masud, Bakar, & Yussof, 2016) (Al Ruwaihthi, 2021). Medical drones offer a revolutionary solution to these challenges by enabling rapid delivery of supplies, overcoming accessibility issues, and providing immediate care (Johnson, Cunningham, Arnold, Rosamond, & Zègre-Hemsey, 2021) (Aggarwal et al., 2023) (Roberts et al., 2023).

Drones have unique capabilities such as vertical take-off and landing, real-time data transmission, and large payload capacity, making them well-suited for emergency medical response (Braun et al., 2019). Global case studies demonstrate the successful implementation of drones in healthcare delivery, highlighting the need for clear regulations and public-private partnerships to ensure successful adoption in countries like Saudi Arabia (Carrillo-Larco, Moscoso-Porras, Taype-Rondan, Ruiz-Alejos, & Bernabe-Ortiz, 2018). The Medidrone system, which effectively transports essential medical equipment showcases the promising potential of drones in Saudi Arabia's healthcare sector (Al-Wathinani et al., 2023). While drones offer immense benefits for emergency medical response, acknowledging their limitations and addressing regulatory, safety and technological hurdles are essential for wider adoption (Amukele, 2019) (Konert, Smereka, & Szarpak, 2019) (Hiebert, Nouvet, Jeyabalan, & Donelle, 2020) (Aggarwal et al., 2023) (Marfo, Asamoah, Owusu-Bio, Marfo, & Kyeremeh, 2023). With proper regulation and ongoing exploration of their capabilities, drones have the power to transform healthcare delivery beyond emergency response (Sham et al., 2022) (Hertelendy, Al-Wathinani, Sultan, & Goniewicz, 2023)

## 2. Methodology (Materials and methods):

Innovative and emerging technologies are being applied in various fields, and it is important to study their impact on a case by case basis to extract practical lessons (Zainal, 2007) , (Krusenvik, 2016). For this study, the researchers opted for a multiple case study approach to draw lessons and make recommendations based on the findings obtained from those cases. The use of unmanned aerial vehicles (UAVs) to improve response time in emergency situations is a widely recognized phenomenon across the globe. Implementation of medical drones in other locations, offering insights and lessons for enhancing emergency medical response. The case of Zipline's Drone Delivery System in Rwanda, where drones are used to transport medical supplies, including blood products, to remote areas has showed improved emergency response by reducing delivery times and ensuring the availability of critical supplies.

Another case is Swiss Air Rescue Rega in Switzerland, which has integrated drones into their emergency response operations. Drones equipped with defibrillators are dispatched to cardiac arrest incidents in remote or hard-to-reach areas, providing life-saving interventions before medical professionals arrive.

The researchers employed a multiple case study approach to examine the impact of drones in healthcare. They analyzed 13 cases where drones were utilized in healthcare settings. These cases were published between 2018 and 2023 and can be accessed through sources like Google Scholar and the National Center for Biotechnology Information website.

Wake Forest Baptist Health in the United States has implemented a medical drone program in rural areas. Drones equipped with medical kits, including automated external defibrillators (AEDs), are dispatched to assist in cardiac arrest cases, resulting in faster response times and increased chances of survival for patients in remote locations.

Key lessons learned from these case studies include the importance of stakeholder collaboration, rigorous training and certification for drone pilots and medical personnel, robust communication systems, the development of operational protocols, and standard operating procedures (SOPs) for drone deployment and emergency response.

When adapting these case studies to the context of Makkah and the Holy Sites, it is crucial to consider the unique characteristics and requirements of the area. Factors such as high population density, large crowds during pilgrimage seasons, and specific geographical features should be taken into account. Local regulatory frameworks, infrastructure, and cultural sensitivities should also be considered when designing and implementing medical drone programs in these locations. It is important to note that while there are numerous published case studies on drone usage, this research specifically focused on cases involving drones in healthcare. As a result, only 13 cases that met the inclusion criteria were selected for analysis.

The common thread linking these case studies to the challenges faced during Ramadan and Hajj seasons is the crucial need for reduced response times in hard-to-reach areas. By drawing on the lessons learned from successful global implementations and meticulously addressing the specific context of Makkah, medical drones can become a powerful tool for transforming emergency response and saving lives in this unique and sacred setting.

### 3. Results and Discussion:

Medical drones have the potential to greatly improve emergency medical response in Makkah and the Holy Sites by providing quick access to critical care. However, there are several challenges that need to be addressed to ensure the safe and effective deployment of medical drones in this unique environment. These challenges are discussed in detail, and solutions are provided to address them.

**3.1 The Integrating medical drones into the emergency response system:** In the event of an emergency in Makkah and the holy sites, there are many stakeholders involved who must work together to ensure an effective response. One potential solution is to integrate emergency medical drones into the response systems. However, this requires careful planning, clear communication channels, and specific roles to be established between all stakeholders involved in serving pilgrims and Umrah performers (as shown in Figure -1). To achieve this, it is important to provide individuals with drone operation skills and knowledge of emergency procedures through training programs. Additionally, standard operating procedures, response protocols, and seamless coordination within the incident command structure must be established and integrated. Regular training and exercises can help identify operational gaps and improve the integration process.

**3.2 Regulatory and Safety Considerations:** When it comes to operating medical drones in restricted areas like the Makkah site, it's essential to consult with local authorities and aviation experts for guidance and requirements. This involves obtaining special permissions and permits, adhering to local aviation regulations, and creating standard

operating procedures (SOPs) for drone operations. To ensure safety and security, it's important to conduct comprehensive risk assessments, implement robust flight planning and control procedures, use collision avoidance techniques, ensure data security and privacy, establish emergency response protocols, provide training and qualifications for drone operators, and communicate with the local community and stakeholders.

**3.3 High population density:** During the Hajj season, the population in Makkah and the holy sites increases significantly, posing a challenge. Drones intended to operate in this environment must be equipped for the specific conditions to prevent potential harm to people.

**3.4 The Specific Geographical Features of Makkah and the Holy Sites:** The mountainous terrain, narrow passages, high-rise buildings, and noticeable landmarks define Makkah. Drones working in the area must be well-equipped to handle the environment.

**3.5 Existing Infrastructure:** A notable challenge that faces the use of drones in emergency healthcare is the infrastructure, particularly the physical infrastructure and the equipment needed to load and unload the drones. Unlike other uses of drones, using drones in medical emergencies includes carrying sensitive material, so special care is needed, and that requires specialized infrastructure.

**3.6 Respecting the Cultural Sensitivities of Both the local Community and Visitors:** Some individuals have cultural or religious concerns when it comes to drones flying over their areas, they consider to be private. Drones have the ability to intrude on personal property and can pose a threat to people's safety. Therefore, any drone operation should take these factors into consideration.

**3.7 A Framework for Adopting the Use of UAVs in Enhancing Emergency Medical Response:** Based on the study, it is evident that there is a need for a comprehensive framework to manage the dynamic relationships between various stakeholders who have an interest or responsibility in using UAVs. The proposed framework divides all stakeholders into nine groups, as depicted in Figure -1

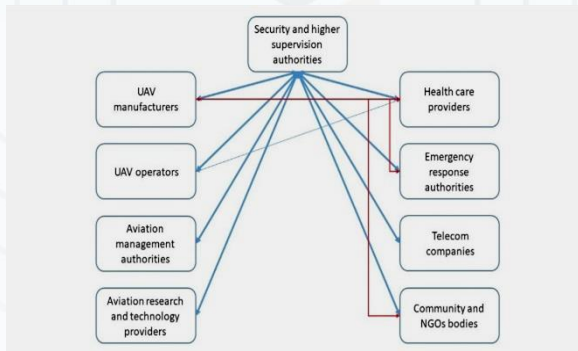


Figure 1. A proposed framework for adopting the use of UAVs in enhancing emergency medical response in Makkah and the Holy Sites.

The framework comprises distinct groups that represent stakeholders with different roles related to their respective titles. Here's a breakdown of the key roles and responsibilities of each stakeholder:

1. Security and higher supervision authorities - This group includes Hajj supreme committee, the ministry of interior, and other relevant authorities.
2. Health care providers - This group comprises hospitals, clinics, blood banks, and other similar entities.
3. Emergency response authorities - This group includes civil defense, municipalities, and other similar entities.

4. Telecom companies - This group includes STC, Mobily, and other relevant companies.
5. Community and NGOs bodies - This group includes Hajj missions, volunteer groups, and other similar entities.
6. UAV manufacturers.
7. UAV operators.
8. Aviation management authorities - This group includes General Authority of Civil Aviation, Saudi air force and other relevant authorities.
9. Aviation research and technology providers - This group includes universities and technology developers.

The framework helps to establish a collaborative stakeholder coordination process between stakeholders based on two factors. The first is the stakeholder's specialty, ensuring that only relevant stakeholders are involved. The second factor is the mission, which determines which stakeholders are needed. For instance, when determining the operational altitude of drones and managing airspace, healthcare providers are not relevant and should not be consulted. On the other hand, UAV operators are relevant and must be consulted. Similarly, when setting the rules for responding to medical and security emergencies, UAV manufacturers are not relevant, while healthcare providers and emergency response authorities are.

**3.8 Proposed Five-Phase Pathway for the Use of Drones to Improve Emergency Response:** A proposed pathway consisting of five phases has been identified for the effective utilization of drones in improving emergency response during medical situations during the Hajj period and the month of Ramadan. The following are the sequential phases to be followed:

**Phase 1: Planning and Feasibility Assessment:** Evaluate the existing state of emergency response and patient care during the Hajj and Ramadan periods. Identify specific challenges and areas where drones can offer significant enhancements. Assess the feasibility of drone usage within the context of the Holy Sites by taking into account airspace regulations, safety considerations, public acceptance, and other relevant factors.

**Phase 2: Drone Selection and Development:** Select suitable drone models based on factors such as payload capacity, range, endurance, and technical specifications. Develop or modify drone technology specifically for healthcare applications, incorporating features like medical equipment delivery systems, real-time data transmission capabilities, and autonomous flight capabilities. Conduct comprehensive testing and evaluation of drone systems to ensure reliability, safety, and adherence to regulatory standards.

**Phase 3: Infrastructure and Operational Setup:** Establish a dedicated drone command center equipped with advanced monitoring and communication systems. Formulate clear operational procedures for drone flights, including pre-flight checklists, emergency protocols, and communication guidelines. Provide specialized training to drone operators and medical personnel regarding the use of drone technology for emergency response and patient care.

**Phase 4: Pilot Testing and Refinement:** Conduct controlled pilot testing of drone operations to assess performance, identify potential issues, and refine operational procedures. Collect feedback from healthcare providers, emergency responders, and pilgrims to enhance the integration of drones into the emergency response system. Continuously monitor and evaluate drone performance during pilot testing to ensure safety, effectiveness, and compliance with regulations.

**Phase 5: Full-Scale Implementation and Monitoring:** Gradually expand drone operations to cover the entire duration of the Hajj and Ramadan periods, ensuring comprehensive coverage and efficient utilization of drone resources. Continuously monitor and evaluate drone performance during full-scale implementation, making necessary adjustments

to optimize operations and address emerging challenges. Collect data on the impact of drone technology on emergency response times, patient outcomes, and overall healthcare delivery during the Hajj and Ramadan periods.

**3.9 A prospect for Artificial Intelligence (AI):** AI is a rapidly developing technology that has the potential to revolutionize every aspect of modern life, including the use of drones in emergency healthcare. AI can benefit medical drone operations in Makkah by improving intelligent guidance and navigation, enhancing safety through automated collision avoidance systems and flight control, enabling real-time monitoring and data analysis to improve operations, facilitating predictive maintenance for medical drones, and improving situational awareness through image and object recognition.

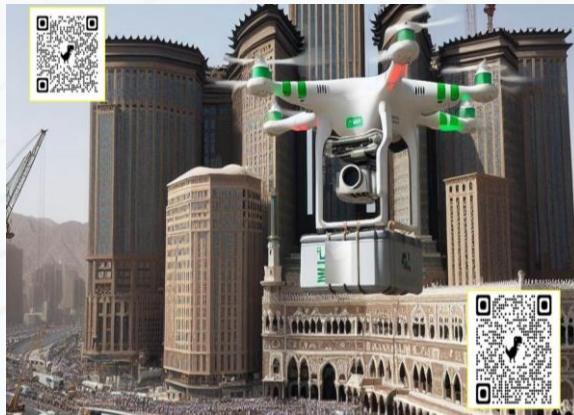


Figure - 2 An imaginary image of a drone flying in crowded area. a picture produced by AI Dall E-3

#### 4. Conclusions:

In conclusion, the utilization of medical drones has the potential to bring about significant transformations in emergency medical response within Makkah and the Holy Sites. These drones can offer expedited access to critical medical care, leading to life-saving interventions and improved patient outcomes. However, the deployment of medical drones in this unique environment necessitates the resolution of various challenges. Collaboration among policymakers, healthcare providers, and other stakeholders is essential to overcome these challenges and actualize the use of medical drones in Makkah and the holy sites. The suggested framework serves as a valuable tool to facilitate the necessary coordination, while the five phases outlined in the study can provide a practical foundation for an implementation plan.

With the continuous increase in the number of pilgrims visiting Makkah and the Holy Sites, expanding the operations of medical drones could effectively address the growing demand for emergency medical services. By harnessing the capabilities of medical drones, the healthcare system can better respond to emergencies and ensure prompt access to critical medical assistance for pilgrims in need.

#### 5. Recommendations:

- Further research is recommended to advance the knowledge of using drones for medical emergency response in this area. The framework proposed here offers a high-level view of collaboration between stakeholders.
- More work is needed to explore the detailed relationship between stakeholders and to provide guidance in the collaboration process.
- Additionally, deeper research is recommended to identify the wider array of challenges that hinder the management of airspace.



- The safety of people is a significant concern in the operation of drones in a densely populated and mountainous area, and therefore, further work is recommended in this regard.
- Establish an electronic platform aims to revolutionize emergency healthcare delivery by connecting healthcare practitioners and life-saving equipment using drone technology. Inspired by ride-hailing apps, this platform would streamline the dispatch of medical personnel and resources to critical emergencies, saving lives and improving outcomes.
- To attract healthcare practitioners, their responses to emergencies would be counted as volunteer hours or recognized through public events. However, challenges such as patient data privacy, infrastructure development, and public acceptance need to be addressed.
- Suggestions include utilizing AI systems, implementing strong security measures, and collaborating with relevant organizations. The ultimate goal is to create an effective system that elevates emergency patient care through drone technology and community member training in basic first aid.

#### References:

- Aggarwal, S., Gupta, P., Mahajan, N., Balaji, S., Singh, K. J., Bhargava, B., & Panda, S. (2023). Implementation of drone based delivery of medical supplies in North-East India: experiences, challenges and adopted strategies. *Front Public Health*, 11, 1128886. doi:10.3389/fpubh.2023.1128886
- Al-Masud, S. M. R., Bakar, A. A., & Yussof, S. (2016). Determining the types of diseases and emergency issues in Pilgrims during Hajj: A literature review. *Stat Inf*, 5 (7)
- Al-Wathinani, A. M., Alhallaq, M. A., Borowska-Stefańska, M., Wiśniewski, S., Sultan, M. A. S., Samman, O. Y., . . . Goniewicz, K. (2023). Elevating Healthcare: Rapid Literature Review on Drone Applications for Streamlining Disaster Management and Prehospital Care in Saudi Arabia. Paper presented at the Healthcare.
- Al Ruwaithi, A. A. (2021). The emergency medical services delivery in mass gathering events: a case study of the Hajj: University of Delaware.
- Amukele, T. (2019). Current State of Drones in Healthcare: Challenges and Opportunities. *The Journal of Applied Laboratory Medicine*, 4(2), 296-298. doi:10.1373/jalm.2019.030106
- Braun, J., Gertz, S. D., Furer, A., Bader, T., Frenkel, H., Chen, J., . . . Nachman, D. (2019). The promising future of drones in prehospital medical care and its application to battlefield medicine. *Journal of trauma and acute care surgery*, 87(1S), S28-S34.
- Carrillo-Larco, R., Moscoso-Porras, M., Taype-Rondan, A., Ruiz-Alejos, A., & Bernabe-Ortiz, A. (2018). The use of unmanned aerial vehicles for health purposes: a systematic review of experimental studies. *Global health, epidemiology and genomics*, 3, e13.
- Hertelendy, A. J., Al-Wathinani, A. M., Sultan, M. A. S., & Goniewicz, K. (2023). Health sector transformation in Saudi Arabia: the integration of drones to augment disaster and prehospital care delivery. *Disaster medicine and public health preparedness*, 1-4.
- Hiebert, B., Nouvet, E., Jeyabalan, V., & Donelle, L. (2020). The application of drones in healthcare and health-related services in north america: A scoping review. *Drones*, 4(3), 30.
- Johnson, A. M., Cunningham, C. J., Arnold, E., Rosamond, W. D., & Zègre-Hemsey, J. K. (2021). Impact of using drones in emergency medicine: What does the future hold? *Open Access Emergency Medicine*, 487-498.
- Konert, A., Smereka, J., & Szarpak, L. (2019). The use of drones in emergency medicine: practical and legal aspects. *Emergency medicine international*, 2019.
- Krusenvik, L. (2016). Using case studies as a scientific method: Advantages and disadvantages. In.
- Leggio, W. J., Mobrad, A., D'Alessandro, K. J., Krtek, M. G., Alrazeeni, D. M., Sami, M. A., & Raynovich, W. (2016). Experiencing emergency medical services at Hajj. *Australasian Journal of Paramedicine*, 13, 1-10.

- Marfo, J. S., Asamoah, P., Owusu-Bio, M. K., Marfo, A. F. A., & Kyeremeh, K. (2023). Exploring Factors Affecting the Adoption and Continuance Usage of Drone in Healthcare: The Role of the Environment. medRxiv, 2023.2005.2004.23289511. doi:10.1101/2023.05.04.23289511
- Roberts, N. B., Ager, E., Leith, T., Lott, I., Mason-Maready, M., Nix, T., . . . Brent, C. (2023). Current summary of the evidence in drone-based emergency medical services care. Resuscitation Plus, 13, 100347 .
- Sham, R., Siau, C. S., Tan, S., Kiu, D. C., Sabhi, H., Thew, H. Z., . . . Ramli, M. H. M. (2022). Drone usage for medicine and vaccine delivery during the COVID-19 pandemic: attitude of health care workers in rural medical centres. Drones, 6(5), 109 .
- Shujaa, A., & Alhamid, S. (2015). Health response to Hajj mass gathering from emergency perspective, narrative review. Turkish journal of emergency medicine, 15(4), 172-176 .
- Zainal, Z. (2007). Case study as a research method. Jurnal kemanusiaan, 5 .(1)



Figure - 3 An imaginary image of a drone flying in a crowded area. a picture produced by AI Dall E-3



- Figure4 An imaginary image of a drone flying in a crowded area. a picture produced by AI Dall E-3



## Cognitive Forecasting of the Safety of Rahmani Crowds from the Perspective of Emergency Medical Services

Haitham Mohammed Milibari<sup>1\*</sup>, Mohammed Awaid Al herim<sup>2</sup>

1- Master of Crowd Management, Umm Al-Qura University, 2- Bachelor of Business Administration (King Faisal University in Al-Ahsa) Department.

\*Corresponding author: E-mail (emt-p997@hotmail.com)

### الاستشراف المعرفي لسلامة الحشود الرحمانية الصحية من منظور الخدمات الطبية الإسعافية

هيثم محمد مليباري<sup>1\*</sup>، محمد عواد الهرم<sup>2</sup>

1- ماجستير إدارة حشود، جامعة أم القرى، 2- بكالوريوس إدارة أعمال، جامعة الملك فيصل بالأحساء.

#### الملخص

تهدف الدراسة إلى وضع المرتكزات الأساسية التي تحتاجها الخدمات الطبية الإسعافية لإدارة الحشود من خلال منظور التنبؤ باستخدام الوسائل التقنية الحديثة والتي هي أحد أسس رؤية المملكة 2023، كما تُظهر الدراسة أهمية (التوحد) في مجال تبادل المعلومات والبيانات فيما يخص التخطيط الاستراتيجي أو التشغيلي وكذلك المعلومات الأساسية والصحية للحاج والمعتمر، والتي قد تُسهم في تغيير انتشار الفرق الإسعافية لخدمة الحشود الرحمانية، وتبنت الدراسة المنهج الوصفي التحليلي والتي تساعد على فحص الخصائص المتوفرة وتحليل المعلومات الموجودة، وقد أوصت الدراسة على ضرورة وجود منصة موحدة بين كافة الجهات التي تخدم ضيوف الرحمن للاطلاع على خططها بهذا الخصوص وهذا الأمر يجعلنا نعزز استخدام التقنية الحديثة في هذا المجال أو حتى مجالات أخرى كتتبع التنبؤ بمناطق الضعف خلال حركة الحشود، هذا بالإضافة للتدريب المستمر لكافة المشاركين في الحج والعمرة للإسعافات الأولية وأي خدمة إسعافية قد يحتاجها الحاج والمعتمر، وكذلك تفعيل الشراكات بين كافة القطاعات الحكومية والخاصة التي تسعى لتأمين سلامة الحشود الرحمانية.

الكلمات الدالة: الاستشراف المعرفي، الحشود الرحمانية، الطوارئ الإسعافية في مرحلة ما قبل المستشفى، الحشود، التجمعات الكبيرة أو الجماهيرية، التكنولوجيا، الذكاء الاصطناعي، مواسم الحشود المتعددة في المملكة العربية السعودية.

#### Abstract

From the title of the study "Cognitive Forecasting of the Safety of Rahmani Crowds from the Perspective of Emergency Medical Services" It aims to establish the basic foundations that emergency medical services need to manage crowds through the perspective of forecasting the use of modern technical means, which is one of the foundations of the Kingdom's Vision 2023. Furthermore, it is showing the importance (unification) in exchange of information and data regarding strategic or operational planning in addition to basic of personal and health information for Hajj and Umrah pilgrim, which may contribute to changing the spread of ambulance teams to serve the Rahmani crowds. The study

methodology is descriptive analytical approach, which helps to examine the available characteristics and analyze the existing information from previous studies, The study recommended the necessity of having a unified platform among all entities that serve the guests of God to view their plans in this regard, and this makes us enhance the use of modern technology in this field or even other fields, such as tracking and predicting weak areas during crowd movement. In addition, to continuous training for all participants in Hajj and Umrah regarding first aid and any emergency service that the Hajj and Umrah pilgrims may need. As well as, activating partnerships between all governmental and private sectors that seek to ensure the safety of the Rahmani crowds.

**Keywords:** Cognitive Foresight, Rahmaniya Crowds, Pre-hospital Emergency Care, Crowd, Large Gatherings or Mass Gatherings, Technology, Artificial Intelligence, Seasons of Multiple Crowds in Saudi Arabia.

## 1. Introduction

The world is currently experiencing a period marked by profound social and cultural transformations. Religious events, particularly the Rahmaniya crowds, characterized by massive participation of believers, stand out as contexts requiring deep thought and comprehensive analysis to ensure the safety of participants. In this context, this research aims to explore and understand the emergency dimensions of the health safety of Rahmaniya crowds.

Hajj, as one of the largest gatherings worldwide, is characterized by geographical, ethnic, and cultural diversity. Pilgrims face health challenges due to their social, demographic, and health diversity. The crowds of Hajj and Umrah are meticulously organized and managed, with Hajj being the largest recurring global annual event. In this context, the Kingdom of Saudi Arabia has gained rich experience in managing the crowds of Hajj and Umrah throughout its history. Crowd medicine is a crucial aspect of both medical and health management, especially in managing the crowds of Hajj and Umrah, linking this branch to the provision and management of health services alongside the security services system, logistical services for supply and sustenance, accommodation services, and transportation services.

The importance of crowd medicine is increasing in the comprehensive system for managing the crowds of Hajj and Umrah. Any deficiency in other components of this system leads to an increase in morbidity and adds a greater burden to crowd medicine. Crowd medicine encompasses more than conventional health services, including medical services for crowd events, monitoring services for prevalent infectious diseases, infection prevention and control services, environmental health considerations, and considerations for food, water, psychological, and social health.

The research title, "Proactive Knowledge Exploration of Health Safety for the Rahmaniya Crowds from the Perspective of Emergency Medical Services," reflects a commitment to understanding the depths of challenges and opportunities in this unique context. The research will focus on analyzing and evaluating key pillars that support emergency medical services in the pre-hospital stage, with a particular emphasis on proactive knowledge as a primary tool for providing a future vision to enhance service quality and ensure participant safety.

The research sheds light on aspirations and challenges related to ensuring the emergency health safety of Rahmaniya crowds, providing recommendations and suggestions to enhance the proper and effective interaction of emergency services. Through a thorough examination and in-depth exploration, the research seeks to make a valuable contribution to enhancing the safety of Rahmaniya crowds and achieving a secure and healthy religious experience.

The study's central questions revolve around:

- The significance of unifying data and information for Hajj and Umrah participants across service sectors, regardless of their nature.

- The effectiveness of utilizing modern technology for predicting pre-hospital emergency medical services interactions with Rahmaniya crowds.
- The effectiveness of continuous training for all parties involved in serving the guests of the Rahman in maintaining the health safety and security of the crowds.

### 1.1 Study Objectives:

1. Identify and analyze the risks and challenges that may confront the crowds of the guests of the Rahman regarding emergency medical services.
2. Highlight the importance of training and education for entities directly involved with the guests of the Rahman to ensure proper response in cases of disasters and multiple injuries among the crowds of the guests of the Rahman, specifically concerning emergency medical services.
3. Utilize artificial intelligence programs to monitor crowds and make informed decisions, whether for prediction or response, regarding emergency medical services.

### 1.2 Study Significance:

The study, in its novelty and content, is significant in both Arabic and English languages, as it combines crowd management with one of its operational pillars, specifically emergency medical services.

The importance of the research lies in enhancing our understanding of the factors influencing the health safety of Rahmaniya crowds and how to improve emergency medical services to achieve a safe and healthy religious experience for participants. The research seeks a better understanding of the health needs of pilgrims and aims to provide guidance that enhances their safety, contributing to creating a safer health environment during Rahmaniya crowd events. Additionally, the research promotes integration between medical services and healthcare, improving the quality of care provided and achieving a comprehensive health experience. The significance can be divided as follows:

- 1- Scientific Significance: The cognitive foresight of the health safety of Rahmaniya crowds from the perspective of emergency medical services holds scientific importance in understanding how to enhance the readiness and response of medical services to emergencies in a way that promotes crowd safety.
- 2- Practical Significance: This research can contribute to the development of procedures and policies to improve the performance of emergency services and enhance public safety in the context of health emergencies.

### 1.3 Study Terminology:

**Cognitive Foresight:** Cognitive foresight is an approach in knowledge management that focuses on using information and analytics to anticipate the future and make strategic decisions. This term relies on prediction and inference techniques to understand future trends and potential risks. Cognitive foresight is employed in a wide range of fields, from strategic planning to predicting economic and social developments (Saritas & Basmaci, 2017, p. 326).

**Rahmaniya Crowds:** Refers to a large gathering of individuals, such as those participating in the events of Hajj or Umrah. These crowds form during the seasons of Hajj and Umrah when Muslims from around the world converge on the holy sites in Saudi Arabia. The purpose of this massive assembly is to fulfill the religious obligation and draw closer to Allah.

**Pre-hospital Emergency Care:** Medical care provided to individuals in cases of health emergencies before they are transported to the hospital. This care includes first aid and necessary medical interventions to preserve the lives of the injured or ill individuals and improve their condition before they reach specialized healthcare facilities in the hospital.

**Crowds:** Refers to a large gathering of individuals in a specific place and at a particular time. Crowds are typically formed due to a special event or occasion, which can include people gathering for religious, social, political, or other purposes. The term "crowds" reflects the collective idea of people coming together and densely congregating within a defined area.

**Large Gatherings or Mass Gatherings:** A significant assembly of individuals in a specific location, often for the purpose of witnessing sports events, participating in protests, attending cultural events, or any other mass public event. This term reflects the idea of collective gathering and social interaction in a specific context.

**Technology:** The use of science and knowledge to develop and apply tools, systems, and processes that contribute to improving human life and meeting societal needs. Technology is multidimensional and encompasses fields such as communications, medicine, energy, information technology, and others (Al-Fadil, 2022, p. 12).

**Artificial Intelligence:** A branch of computer science that focuses on developing technological systems capable of executing tasks that require intelligent thinking. The goal of artificial intelligence is to design and develop software and systems that can simulate human cognitive abilities, such as linguistic understanding, problem-solving, and decision-making.

**Seasons of Multiple Crowds in Saudi Arabia:** These are seasons that involve the presence of large crowds within the Kingdom of Saudi Arabia. The Hajj season is the main event that witnesses a significant gathering of crowds in the Kingdom. It occurs during the month of Dhu al-Hijjah in the Hijri calendar and constitutes one of the Five Pillars of Islam. During this time, Muslims from around the world come to perform the Hajj pilgrimage in Mecca. Additionally, there is another season known as the Umrah season, which continues throughout the year. It also sees crowds heading to Mecca to perform the Umrah pilgrimage. Furthermore, other gatherings occur during specific religious or cultural events, but the Hajj season is considered the most prominent and impactful in terms of crowd gathering in Saudi Arabia.

#### 1.4 Spatial Framework of the Study:

Mecca, the Holy Sites, and the Sacred Kaaba.

#### 1.5 Temporal Framework of the Study:

Major religious crowd seasons in the Kingdom of Saudi Arabia (Hajj and Umrah seasons).

#### 1.6 Study Methodology:

Due to the nature and specificity of the research, adopting a descriptive approach was imposed, which plays a crucial role in accurately and comprehensively depicting phenomena and conditions. The descriptive method allows researchers and scholars to examine the main characteristics of the study variables without focusing on deep interpretation or analysis. The descriptive approach contributes to clarifying and describing relevant phenomena. (Suleiman, 2014, P130)

Based on this, the method of data collection and analysis in this research will rely on the (simple observation) approach, which involves observing phenomena and events spontaneously without subjecting them to scientific control variables or conditions (Khemkhani, 2017).

#### 1.7 Previous Studies:

**Al-Fadil and others (2022)** conducted a study that reviews the potential positive impact of using modern technologies in managing and organizing the behavior of pilgrims and Umrah performers, with a focus on achieving the goals of the Kingdom's Vision 2030. The study adopted a descriptive methodology, where a survey was employed as the primary data collection tool. The results highlighted the importance of the necessity to guide and raise awareness among pilgrims and

Umrah performers by Hajj and Umrah offices and pilgrimage institutions about the potential benefits of using modern technologies. Such guidance contributes to achieving better organization and effective crowd management.

**Ayyad Study, (2021)** the Ayyad study aims to understand the impact of electronic management on improving crowd control. Using a descriptive survey methodology and a directed questionnaire for 250 workers in the Hajj and Umrah system, the results show that electronic management significantly enhances organization and monitoring. Electronic tools and technologies facilitate communication and information exchange, thereby enhancing the overall effectiveness of crowd management and organization. This contributes to a greater improvement in the experience of participants and demonstrates high proficiency in digital crowd monitoring and effective crowd management.

**Al-Areeshi Study, (2019)** the Al-Areeshi study seeks to analyze the integration between individuals in pilgrimage zones, transportation means, and service facilities. The research relies on integrating the Internet of Things with other technologies to monitor these elements, using a descriptive survey methodology. The study focuses on leveraging mobile phone network data to enhance the Internet of Things system. This provides authorities managing pilgrim crowds with software applications designed to improve crowd management planning and real-time decision-making without impacting current network structures.

**Al-Sha'ari Study and Others, (2021)** the Al-Sha'ari and colleagues study aims to design a simulator based on realistic engineering principles for crowd management. It highlights the importance of making appropriate decisions for managing the movement of Rahmaniya crowds. The study emphasizes that creating and innovating a virtual environment using modern technology, specifically simulation, will help develop various scenarios in multiple locations visited by the guests of Rahman. The study underscores the importance of using modern technological methods for crowd management by generating virtual data.

### **1.8 Study Differentiators:**

The study stands out for its uniqueness and distinctiveness in its compact size and its inclusion of both Arabic and English languages. This research is novel as it combines crowd management with a specific operational aspect, namely, emergency medical services.

## **2. The Theoretical Framework:**

### **2.1 Concept of Crowds and Large Gatherings:**

The term 'crowd' refers to a collective gathering consisting of individuals who quickly respond to a specific invitation, agreeing to meet at a designated place and time to achieve a common goal. In the modern era, this term is primarily used to describe massive human gatherings, where the number of attendees may exceed one million people simultaneously. The term reflects the rapid response and organization of the group to achieve specific objectives, as individuals gather in a location with relative spatial boundaries (Yezli & Alotaibi, 2019). Large gatherings represent a social phenomenon involving the assembly of massive numbers of individuals in one place and during a specific period. These gatherings can result from religious, cultural, sporting, or political events. They are characterized by the diversity and variety of activities, including celebrations, processions, and cultural events. Large gatherings vary in size and impact, ranging from small local events to significant international occurrences. This term highlights the vitality of social connections and the influence that large gatherings can have on both societies and individuals (Al-Rahili, 2018, p. 26).

Among the prominent features of large gatherings is the notable cultural diversity, where individuals from different backgrounds come together and contribute to enriching shared cultural life. These gatherings serve as centers for

economic activities, providing diverse opportunities for employment and business. However, challenges such as increased population density, environmental pollution, and intensive resource consumption emerge. This necessitates consideration for sustainability and effective urban planning to achieve a balance between growth, the well-being of residents, and environmental preservation. These massive gatherings highlight both progress and challenges facing urban societies today (Jonathan, 2017, P2).

## **2.2 The Difference Between Crowd Management and Disaster and Major Incident Management:**

Crowd management (large gatherings) differs from disaster and major incident management in terms of goals and administrative focus. Crowd management involves organizing and overseeing large gatherings of individuals, as seen during the Hajj season, Umrah seasons, festivals, or sports events. The aim is to provide a safe and efficient environment for the crowds, focusing on organizing events, guiding the crowds, and ensuring their comfort (Ayyad, 2021, p. 22).

On the other hand, disaster and major incident management are associated with responding to disasters such as natural emergencies or major accidents. The goal is to provide an effective emergency response and deliver healthcare and first aid, including organizing evacuations, providing shelter, and offering medical care (Abdulhameed, 2018, p. 33).

In summary, the difference between them lies in the fact that crowd management focuses on organizing gatherings and crowds. Errors resulting from this organization, whether from the management or the crowd itself, can lead to disaster and major incident management.

## **2.3 The Concept of Cognitive Foresight and Achieving Excellence in Ensuring the Health Safety of Pilgrims:**

In the context of cognitive foresight, it is associated with anticipating the future and understanding complex contexts to make intelligent decisions. If the goal is to achieve excellence in ensuring the health safety of pilgrims, this implies leveraging predictions and analyses to enhance healthcare systems and responses in the context of massive crowds.

The integration of cognitive foresight with the safety of pilgrims involves anticipating expected health challenges, identifying future needs, and determining how to manage them. This forward-thinking allows for improved preparedness for medical incidents and effective healthcare provision during large religious events. It relies on continuous analysis and innovation in healthcare technology.

Cognitive foresight can be enhanced to achieve excellence in securing the safety of pilgrims, including using technology to monitor medical conditions, providing rapid responses in emergencies, and analyzing health data to guide preventive and therapeutic measures (Eid, 2019, p. 50).

In general, cognitive foresight serves as the foundation for achieving excellence in safeguarding the health safety of pilgrims by developing effective and sustainable responses that align with the challenges of the pilgrimage crowds.

## **2.4 Key Modern Technologies and Practices in the Field of Emergency Medical Services Serving Crowd Management:**

In the field of emergency medical services and crowd management, there are modern technologies and practices that enhance preparedness and control in emergency situations. Some of these technologies and practices include:

### **1. Electronic Health Record (EHR):**

Enables the digital documentation of medical information and instant access to the medical history of patients, specifically pilgrims. Facilitates anticipating and improving diagnosis and treatment during emergency case management. Implemented through applications such as the "Nusuk" app by the Ministry of Hajj and Umrah, the "Sehaty" app by the Ministry of Health, and the "Asefni" app by the Saudi Red Crescent Authority.



## 2. Closed-Circuit Television (CCTV):

Used recently in various fields, including health. During the COVID-19 pandemic, CCTV systems were utilized to monitor human body temperature, contributing to preventing the spread of the virus in specific locations. Tracking physiological indicators (vital signs) in addition to temperature (respiration, pulse, blood pressure, and oxygen saturation) facilitates monitoring the health status of crowds in their locations.

## 3. Artificial Intelligence (AI) Technologies:

Utilizing artificial intelligence (simulation) to analyze massive medical data for crowds. Contributes to making various decisions (health and security) under different scenarios and multiple assumptions. Assists in crowd management (Alshaeri et al., 2021).

## 2.5 Collaboration and Strategic Partnerships with International Organizations and Internal Sectors and Their Significance in Crowd and Emergency Medical Services Management:

Collaboration and strategic partnerships in the management of crowds and emergency medical services play a vital role in achieving the effectiveness and safety of massive events such as the Hajj pilgrimage. Some significances include (Jonathan, 2017, P30-36):

1. Information Exchange and Coordination: Enhances communication among relevant entities, whether internal government, health sectors, and pilgrimage authorities or external international humanitarian organizations. Facilitates data analysis and coordination efforts to maximize the utilization of available resources.
2. Training and Skill Development: Establishes training programs, especially in first aid, specifically addressing common issues during Hajj and Umrah seasons. Targets internal sectors and those specialized in pilgrimage management to enhance skills and improve preparedness for responding to medical emergencies.
3. Joint Planning for Response: Provides a shared platform to display plans of each participating entity in the Hajj and Umrah events, especially concerning the response to medical emergencies. Facilitates improved coordination and information exchange among the responsible authorities during the preparedness phase, enhancing the overall response to emergencies.

The importance of managing medical crowds in the context of religious pilgrimages is significant in several ways:

1. Improving Preparedness and Readiness: Enhances preparedness levels to address health emergencies and unforeseen situations, ensuring better readiness to tackle any unexpected medical challenges.
2. Achieving Healthcare Efficiency: Partnerships with medical organizations and support from international bodies contribute to providing advanced and efficient healthcare for pilgrims, thereby enhancing their health experience during the events.
3. Information Exchange: Unifying the exchange of information among official entities serving pilgrims, as well as service providers from Hajj and Umrah companies, is crucial for standardizing information sources and avoiding duplication and discrepancies.
4. Enhancing Communication: Strengthening communication between different sectors, whether internal or external, ensures better coordination in dealing with complex health situations.
5. Service Integration: Collaborative efforts assist in integrating healthcare and emergency services, promoting seamless organization of responses and reducing gaps in care provision.

In general, these priorities contribute to establishing an effective and integrated healthcare system during periods of religious pilgrimages, enhancing safety, and improving the quality of medical services provided to pilgrims.

### 3. Evaluation and Results:

Studies have demonstrated the effectiveness of information technology in monitoring and analyzing the health conditions of religious pilgrimages. Modern technologies can contribute to anticipating and addressing health risks.

1. **Regular Training for Medical Teams:** Ongoing training for medical teams improves preparedness and response in health emergencies. Training enhances the necessary skills to provide effective care in the context of religious pilgrimages. (Patel, A. D., & Kaufman, J., 2016)

2. **Effective Communication among Stakeholders:** Effective communication among relevant parties enhances smooth coordination in managing health crowds. Coordination contributes to improving the response of medical teams and directing efforts effectively. (Romitia et al, 2023)

3. **Modern Guiding Strategies Address Health Crowd Management Challenges:** Contemporary guiding strategies meet the challenges of managing health crowds during religious pilgrimages. Strategic planning enhances the healthcare system's ability to improve the quality of care in emergency situations. (Al-Mutairi, 2015)

### 4. Recommendations and Practical Applications in the Study:

The core function of emergency services relies on two elements: providing pre-hospital care promptly and transporting patients to the nearest healthcare facility at the appropriate speed. The success indicators for these elements include response time. However, response time faces various operational risks, such as the mismatch between the geographic coverage and the human and mechanical resources available for service delivery. This can impact the rapid response to emergencies and disasters, posing a challenge in crowd management. In light of the discussed and clarified points, the emergency service in the field of crowd management needs:

1. **Technologies and IT:** Embracing modern technology in crowd management and leveraging contemporary technological solutions that support predictive analytics adds crucial elements to emergency service provision. This includes using technologies to predict locations where emergency events might occur during the movement of religious crowds. (Abdul Kareem, 2019)

2. **Training and Development:** Knowledge transfer, especially in the emergency service sector for pilgrims, serves as the frontline defense and support for the core service, reducing response time. Ongoing training and development are essential. (Patel, A. D., & Kaufman, J., 2016)

3. **Communication and Coordination:** Establishing a unified platform for all sectors to present their plans for serving religious crowds opens the door for information exchange and standardization among sectors, addressing issues before they occur. (Romitia et al, 2023)

4. **Enhancing Guidance and Strategic Planning:** Continuing to rely on emergency service deployment within crowd locations under the strategy of increasing the number of pilgrims, as envisioned by the Kingdom's 2023 vision, requires a shift. Innovative planning, such as establishing and dispersing focal points, becomes necessary.

5. **Promoting Community Participation:** Involving the community, both among the religious crowds and in service sectors, in familiarizing them with emergency plans and conducting training sessions enhances overall preparedness. (Patel, A. D., & Kaufman, J., 2016)

## References

### References in Arabic

- Abdul Kareem, Bushra (2019), "Utilizing Information and Communication Technology for Crisis Preparedness and Mitigation of its Impacts," Iraqi Journal of Administrative Sciences, Issue 3, Number 3, Volume 3.
- Al-Areeshi, S. (2019). "The role of the Internet of Things in the smart management of Hajj crowds." Master's thesis, King Saud University. p. 56, Saudi Arabia.
- Abdel-Hameed, R. (2018). "Crisis and disaster management strategy" (3rd ed.). Abu Al-Majd Printing House, Egypt.
- Al-Salmi, M., & Al-Assaf, A. (2020). "The impact of perceived risks on the intention to engage in social and economic activities in the Kingdom of Saudi Arabia." Journal of Administration and Development for Research and Studies, 9(2), Algeria.
- Al-Rahili, N. (2018). "Factors influencing the behaviors of human crowds: A case study of Hajj." The 18th Scientific Forum on Hajj, Umrah, and Visit Research, Institute of Hajj and Umrah Research, Umm Al-Qura University, Mecca, Saudi Arabia.
- Al-Shaeri, et al. (2019). "Development of a simulation system for crowd management and data generation." Institute of Hajj and Umrah Research, Umm Al-Qura University, Mecca, Saudi Arabia, 21st Forum, Saudi Arabia.
- Alfadhil, et al. (2022). "The importance of employing modern technological techniques in organizing and managing the behavior of pilgrims and visitors in light of the Kingdom's Vision 2030." Academic Journal of Research and Studies, Journal of Educational and Social Sciences, 8, Austria.
- Al-Mutairi, Bandar (2015), "The Role of Strategic Planning in Predicting Epidemic Crises: A Perspective from Health Professionals at the Ministry of Health in Riyadh City," Master's Thesis, Prince Naif Arab University for Security Sciences, College of Social and Administrative Sciences, Department of Administrative Sciences, Page 181.
- Ayyad, D. (2021). "The role of e-government in improving crowd management: A perspective from those working in the Hajj and Umrah system." Master's in Hajj and Umrah Management, Journal of Economic, Administrative, and Legal Sciences, 6(6), Umm Al-Qura University, Saudi Arabia.
- Eid, A. (2019). "Towards planning indicators to increase the efficiency of the services provided by Tawaf institutions for the pilgrims of the Holy Kaaba in the era of the service industry." Journal of Umm Al-Qura University for Social Sciences, 12(1), Saudi Arabia.
- Khemkhani, Mubarak (2017), "Methods and Tools for Data Collection," Al-Thakira Journal, Linguistic and Literary Heritage Laboratory, Southeast Algeria, Issue (9).
- Suleiman, Abdul Rahman (2014), "Research Methods," World of Books, College of Education, Ain Shams University.

### References in English

- Jonathan Bundy, (2017), "Crises and Crisis Management Integration", Journal of Management, Arizona State University, USA.
- Patel, A. D., & Kaufman, J. (2016), "Training healthcare professionals for mass-casualty incidents in a virtual emergency department: VED II". Prehospital and Disaster Medicine, 31(5), 494-499.
- Romiti, A., Del Vecchio, M., Cavicchi, C., Vagnoni, E. (2023). "Communication Strategy in Healthcare Organizations During Covid-19 Crisis: Insights from the Italian Context", In: Persiani, N., Vannini, I.E., Romiti, A., Karasavoglou, A., Polychronidou, P. (eds) Challenges of Healthcare Systems in the Era of COVID-19. Contributions to Management Science. Springer, Cham. [https://doi.org/10.1007/978-3-031-43114-2\\_1](https://doi.org/10.1007/978-3-031-43114-2_1)
- Saritas, O., & Basmaci, Y. (2017), "Fuzzy cognitive maps as representations of mental models and group consensus: An empirical investigation". Technological Forecasting and Social Change.



## Healthcare accessibility during Hajj 1444/2023

Khulud K Alharbi<sup>1</sup>, Bayan Hashim Alsharif<sup>\*2</sup>, and Turkey J Arbaein<sup>3</sup>

1- Department of Health Administration and Hospitals, College of Public Health and Health Informatics, Umm Al-Qura University, 2- Director of Hajj and Umrah Research and Epidemiology Administration, Consultant of Preventive Medicine and Public Health, King Abdullah Medical City, 3- Turkey J Arbaein, Department of Health Administration and Hospitals, College of Public Health and Health Informatics, Umm Al-Qura University.

\*Corresponding author: E-mail (Alsharif.b@kmc.med.sa)

## تقييم إمكانية الوصول إلى خدمات الرعاية الصحية في الحج 2023/1444

خلود خالد الحربي<sup>1</sup>، بيان هاشم الشريف<sup>\*2</sup>، تركي جميل أربعين<sup>3</sup>

1- قسم الإدارة الصحية والمستشفيات، كلية الصحة العامة والمعلوماتية الصحية، 2- إدارة أبحاث الحج والعمرة والوبائيات بمدينة الملك عبد الله الطبية

### الملخص

الحج، أحد أكبر التجمعات الدينية السنوية في العالم، يجذب ملايين الحجاج من خلفيات وجنسيات وأعمار وأنحاس متنوعة، وتهدف هذه الدراسة إلى تقييم التحديات التي يواجهها الحجاج عند محاولة الوصول إلى الخدمات الصحية أثناء حجهم. وقد أجريت هذه الدراسة النوعية والكمية خلال موسم حج عام 1444هـ/2023م. أجرى فريق من المتطوعين المؤهلين مقابلات مع الحجاج من خلفيات مختلفة لجمع معلومات حول حصولهم على الخدمات الصحية خلال فترة الحج. شارك في هذه الدراسة ما مجموعه 740 مشاركا، 69.5% من الإناث. وفي إطار إمكانية الوصول إلى الخدمات الطبية، برزت أربعة مواضيع: (1) إمكانية الوصول إلى الخدمات الطبية، بما في ذلك الحواجز اللغوية والبعد عن مرافق الرعاية الصحية؛ و (2) إمكانية الوصول إلى الخدمات الطبية. (2) الملاءمة، مع المشكلات المبلغ عنها في التعامل مع الأدوية؛ (3) التوافر، مع ملاحظة أن بعض الحجاج جلبوا الأدوية من بلدانهم؛ و (4) المقبولية، حيث ربط المشاركون التغيرات المناخية بالتهابات الجهاز التنفسي وأعربوا عن خوفهم من طلب الرعاية الطبية. وقد حددت هذه الدراسة التحديات في تسهيل وصول الحجاج إلى الرعاية الصحية أثناء الحج. وشدد على أهمية الاستراتيجيات والسياسات، بما في ذلك برامج التوعية للحجاج والحجاج، لإنشاء نظام رعاية صحية أكثر إنصافا.

### Abstract

Background: The Hajj, one of the largest annual religious gatherings in the world, attracts millions of pilgrims from diverse backgrounds, nationalities, ages, and genders. This study aimed to evaluate the challenges pilgrims encounter when trying to access health services during their pilgrimage. This qualitative and quantitative study was conducted during the Hajj season of 1444 AH/2023. A team of qualified volunteers interviewed pilgrims from different backgrounds to collect information on their access to health services during the Hajj period. A total of 740 participants, with 69.5% females, were involved in this study. Under medical service accessibility, four themes emerged: (1) approachability, encompassing language barriers and distance from healthcare facilities; (2) appropriateness, with reported issues in handling

medications; (3) availability, noting some pilgrims brought medication from their countries; and (4) acceptability, where participants associated weather changes with respiratory infections and expressed fear of seeking medical care. This study identified challenges in facilitating pilgrims' healthcare access during Hajj. It emphasized the importance of strategies and policies, including awareness programs for Hajj workers and pilgrims, to create a more equitable healthcare system.

**Keywords:** health need assessment, Healthcare accessibility, Hajj, Mass gathering, Saudi Arabia, Makkah.

## 1. Introduction

Mass gatherings (MG), characterized by the assembly of large numbers of individuals, such as religious events, festivals, and sporting competitions, are a distinctive feature of the global society (1). In 2015, the World Health Organization (WHO) defined MG as "characterized by the concentration of people at a specific location for a specific purpose over a set period and which has the potential to strain the planning and response resources of the country or Community" (2). Mass gatherings can cause substantial public health problems, impacting the health of attendees, the host country's population, and health services responsible for managing health-related issues (3). The Kingdom of Saudi Arabia (KSA) hosts one of the largest gatherings per year, as millions of Muslims travel from all over the world during the month of Dhul-Hijjah to participate in the Hajj (2)(3), which is one of the five main pillars of Islam. Therefore, all Muslims are required to make a trip to Makkah once in their lifetime (4)(5). This large MG, including overcrowded housing, assemblages, and prayers, is associated with several significant public health challenges (6). Communicable illnesses include influenza, influenza-like sickness, viral hemorrhagic fever, meningococcal disease, yellow fever, polio, cholera, plague, tuberculosis, gastrointestinal infections, and foodborne diseases, such as food poisoning and diarrhea. Due to physical exertion and overcrowding, some pre-existing chronic diseases (e.g., heart disease, asthma, chronic chest conditions, diabetes, and renal and liver diseases) may become harmful, particularly for older adults, facilitating the spread of communicable diseases, specifically non-chronic or infectious diseases.

Pilgrims proceeding to Hajj are susceptible to multiple and significant health risks because Hajj takes place during a limited period, the geographical area of this religious event is limited, and the large number of attendees (approximately two million people) (7). A World Health Organization (WHO) study, covering the period from 2005 to 2014, investigated health risks and services during Hajj. The findings categorized results into three main areas: health services, non-communicable illnesses, and communicable diseases. Despite ongoing developments, each Hajj season introduces new public health challenges, highlighting the need for improved health management of the pilgrimage.

Healthcare service accessibility during MG is a complex and urgent concern, carrying implications for public health and safety. A literature review conducted on health issues during Hajj in 2019 revealed that despite the Saudi government providing free health services for all pilgrims, a limited number of studies, primarily focused on hospitals, have explored these services (8). Saudi Arabia's Ministry of Health provides free healthcare services to all pilgrims. In the 1444 Islamic calendar or 2023 Gregorian calendar, Makkah and Al Madinah's healthcare system comprised 32 hospitals supported by 140 primary healthcare centres, with a total bed capacity increased to 6,132 beds. Specifically, 222 beds were allocated for heatstroke cases, and medical points were established on the Al-Mashaer and Al-Haramain trains. In addition, the Ministry provided 190 ambulances and set up 16 emergency centres at the Jamarat Bridge facility in Mina. Managed by 32,000 healthcare providers, including visiting international practitioners, this system offers curative and preventive services to pilgrims (9). The accessibility of healthcare services for pilgrims is a pressing issue that has not received adequate attention in the existing literature. These pilgrims who travel long distances to visit religious sites, often face

challenges in accessing healthcare services during their journeys. However, studies on this topic are noticeably scarce, leaving a gap in the understanding of the healthcare needs and experiences of pilgrims. By comprehensively understanding these components and their interrelationships, this study aims to provide insights and recommendations for optimizing healthcare accessibility during mass gatherings. These insights can assist event organizers, healthcare professionals, and public health authorities in enhancing the overall success and safety of the Hajj journey.

## 2. Methodology (Materials and methods)

**Primary objective** To gain an understanding of pilgrims' health issues, needs, and accessibility to healthcare during Hajj 2023

**Study setting** This is a mixed qualitative and quantitative design study conducted in Makkah city designed to glean insight into pilgrims' health needs throughout their journey during Hajj season 1444 AH / 2023 AD. Saudi Arabia received 1,845,045 pilgrims from more than 150 countries during Hajj this year (1).

**Participants** We interviewed adult pilgrims from various countries who could communicate in either Arabic or English. Participants were chosen using convenience sampling. Voice consent was taken to record the conversation from all participants in the research. Pilgrims were recruited in the following days of the Hijri calendar: from 8 Dhu al-Hijjah 1444 to 12 Dhu al-Hijjah 1444, which corresponds to the Gregorian calendar from 26 June 2023 to 30 June 2023.

**Data collection** The researchers identified the tent sites of Arabic-speaking and English-speaking pilgrims and divided the data collectors according to the language in which they could communicate with the pilgrims.

A total of 16 trained qualified volunteers visited the holy sites in Makkah (Mina and Arafah) and conducted face-to-face in-depth interviews focusing on the social demographics of the pilgrims; under the supervision of (KA). Following this, a detailed questionnaire was utilized to assess pilgrims' health needs and evaluate their accessibility to various health services throughout their pilgrimage. The data collection period spanned 7 days, offering a comprehensive snapshot of the health needs and issues faced by the pilgrims during their Hajj experience. Each interview lasted approximately 5-6 minutes and took place at the pilgrims' tent.

**Data analysis** Participant responses were audio-recorded and transcribed verbatim. The Arabic transcripts were directly transcribed into English by the bilingual researchers. After obtaining the data, the researcher read the notes to enhance the clarity of the data. The data was analysed using a thematic analysis approach in which the researchers repeatedly read the data to identify subjects. The researchers plotted the data into the matrix, which was used to compare within and across the pilgrims' views.

**Step 1: Familiarisation** Each author (KA) and (BA) initially read the reported data to become familiar with the content, and to acquire a basic comprehension of the primary themes and topics discussed in the interview. During this stage, the authors took notes on the significant points of interest and potential research questions to be referenced in their discussion.

**Step 2: Initial coding** Transcripts were coded independently by the authors (KA) and (BA). Next, the codes were reviewed for similarities and differences, to identify the common patterns and construct the final codes. The grouping and analysis of similar codes was facilitated using qualitative software NVivo in the coding process.

**Step 3: Categories** The authors began their analysis by identifying the major themes and patterns emerging from the data from the bottom up. This allowed the authors to fully comprehend the subject and identify the most important categories and patterns in the data.

Next, the authors performed a top-down analysis, beginning with a pre-existing knowledge of the subject and working to find categories and patterns that applied to their study question. This method allowed the researchers to analyze the data from a theoretical standpoint by incorporating prior information into their interpretation of the data.

**Step 4: Themes** The authors evaluated the categories, the context in which they were used, and any links between the categories. The analysis produced the themes, patterns, and understandings of the study topic. To guarantee consistency and trustworthiness across the collected data, the data was checked against other sources such as notes made during the interview.

(KA) applied a critical method to the study, questioning potential biases and assumptions in the data. By using this method, the researcher was able to identify areas of contention and disagreement in the data, producing a more complex knowledge of the subject.

**Step 5: Final verification** To confirm the accuracy and dependability of the emerging themes, one additional (TA) author who was not involved in the initial coding was included. The author verified that the codes appropriately matched the substance of the material by examining the list of coded segments. This stage acted as an external check to ensure the authenticity of the coding process.

**Rigour and trustworthiness**

This study employed several quality-checking techniques to guarantee the authenticity and dependability of the results. First, when examining the data, the authors engaged in reflective analysis to examine their preconceptions and prejudices, while assuring that the coding was performed by two separate authors and comparing their findings for agreement. A Discussion was utilized to obtain agreement on all codes and themes. Second, peer review was performed to confirm and assure data support of the findings. Third, we obtained participant comments on our findings to assure that the emergent themes accurately reflected their experiences.

**Ethics approval**

The Institutional Review Board of King Abdullah Medical City (Number 23-1101) approved this study.

**3. Results and Discussion**

**Participants’ characteristics**

A total of 739 Hajji participated in this study. Most of the participants who answered the questionnaire came from a board (472, 63.87%), and were aged between 25–45 (363, 49.12%). Most Hajji were female (513, 69.42%). A history of chronic disease such as diabetes mellitus (DM), hypertension (HTN), asthma, and heart diseases was documented for some of the participants. (Table 1)

Table 1: Demographic characteristics of the participants (n=739)

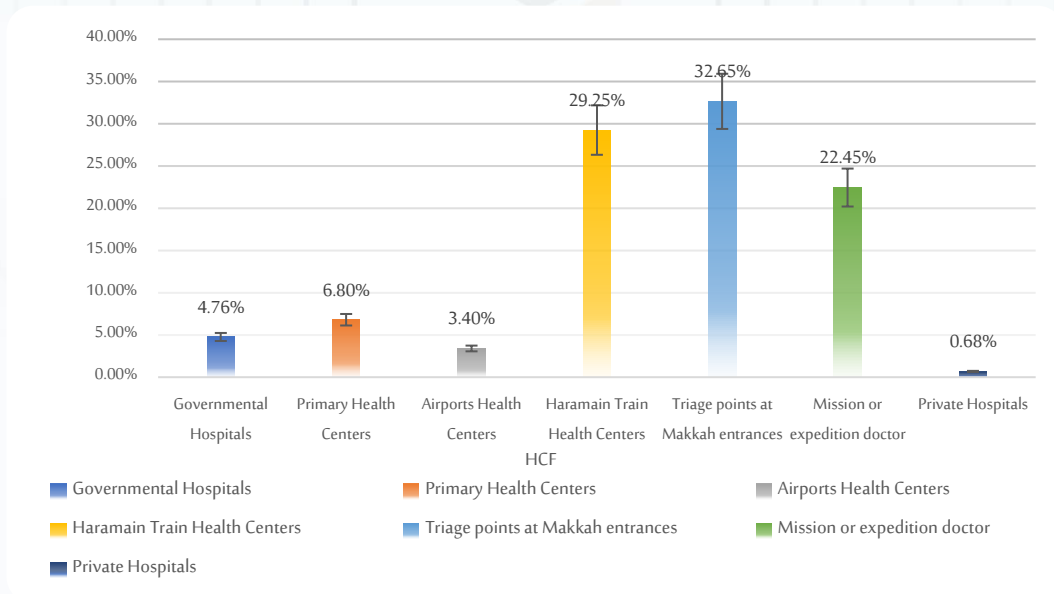
Variable	n(%)
<b>Sex</b>	
Male	226 (30.58)
Female	513 (69.42)
<b>Age Group</b>	
<14	2 (0.27)
15–25	80 (10.83)
26–45	363 (49.12)
46–69	262 (35.45)
>70	32 (4.33)
<b>Saudi vs. Non-Saudi</b>	

Saudi	215 (29.09)
Non-Saudi	524 (70.91)
<b>Arrival</b>	
International	521 (70.50)
Domestic	218 (29.49)
<b>Were you ill during this Hajj season?</b>	
Yes	580 (78.48)
No	159 (21.52)
<b>Chronic Disease</b>	
DM	13
HTN	12
Asthma	3
Thyroid disease	2
Heart disease	3
Allergy	5
Transplants	2

### Accessibility of health services

Our analysis revealed significant convergence between surveys completed during the 2023 Hajj season, indicating that access to medical services remains a major public health challenge. Nearly 20% ( $n=146$ ) of the participants used one of the medical care facilities provided during the 2023 Hajj season. Among study respondents who used medical services, 32.7% were checked at triage points at the Makkah entrance, while 29.3% were checked at Haramain train health centres. An additional 22.4% visited mission or expedition doctors or camp clinics. Finally, less than 5% accessed medical services in governmental hospitals, and nearly 7% accessed primary healthcare centres (Graph 1). Various factors contributed to the accessibility of services including availability, approachability, acceptability, and affordability.

Graph 1 Use of medical services during Hajj 1444/2023





### Approachability of services

The sheer magnitude of the Hajj pilgrimage poses significant challenges in terms of approachability to health services. The influx of pilgrims places immense pressure on the healthcare infrastructure, and the potential for the spread of contagious diseases is always a concern. Therefore, the Saudi Arabian government and relevant authorities must establish a robust healthcare system that can effectively meet the needs of the pilgrims. Additionally, providing multilingual medical staff and volunteers ensures effective communication with pilgrims from different regions.

Accessing medical services is a specific challenge pilgrims encounter. The large crowd makes it difficult to find medical help when needed. As one pilgrim remarked,

*"The main obstacle we encounter is obtaining timely access to medical services. The large crowds can hinder access to medical services, which can be frustrating when immediate care is required."*

Moreover, pilgrims may face challenges in accessing transportation, as another pilgrim stated,

*"It can be a real struggle to find transportation to various clinics, Navigating through crowds can make it hard to find the support we require."*

Due to personal preference a large number of the interviewed people reported, that they did not seek any medical attention during the Hajj journey, as they believed that the symptoms were mild, and they did not see the need for a visit.

*"Mild symptoms, no need for medical attention."*

In general, pilgrims' comfort and well-being are greatly dependent on how approachable the services are during the hajj. The experience of making the pilgrimage is made easier for the millions of pilgrims who visit Mecca every year by offering easily approachable services.

### Acceptability of health services

One important factor affecting accessibility is the availability of acceptable health services. Many participants indicated that they faced a language barrier when seeking healthcare during their journey. The language barrier poses a substantial challenge to effective healthcare delivery. Pilgrims are unable to communicate their symptoms, medical history, or concerns to the healthcare provider due to the lack of a shared language. This can result in misinterpretation, misunderstanding, or even misdiagnosis of their condition.

*"Far from our camp, and I can't understand Arabic and English, no guide available."*

*"Language barrier for Africans; there are no instructions in different languages except Arabic and English; we demand instructions in French."*

Limited healthcare infrastructure or unbalanced distribution often forces individuals to travel long distances to seek medical care, causing unnecessary delays and discomfort. This lack of accessibility can result in delayed or inadequate treatment, exacerbating health conditions and potentially increasing morbidity.

*'I am tired of walking a lot; I cannot reach PHC.'*

The pilgrims may also have different expectations and views regarding healthcare because they come from a variety of ethnic backgrounds. This may make it difficult for the medical professionals to comprehend and meet the pilgrims' needs according to their culture. As one pilgrim stated,

*"not all of the healthcare providers here understand our cultural practices and beliefs, which can affect the care we receive."*

Due to the large number of pilgrims, safety issues, linguistic and cultural obstacles, medical and health services, accommodations and facilities, and other factors, the acceptability of services during the Hajj presents a substantial

challenge. Even with the efforts to resolve these issues, there is still much that can be done to guarantee that every pilgrim has a satisfactory and safe experience on the holy journey.

### Availability of health services

Few pilgrims heavily relied on their medications and remedies, often passed down through generations. They did not seek healthcare services as they lacked a comprehensive plan for accessibility and management of health services. Their inability to find any formal guidelines for healthcare services made them even more dependent on self-sufficiency. The reliance on self-medication and lack of knowledge of healthcare accessibility can lead to adverse consequences. Individuals may delay seeking treatment, leading to an exacerbation of health conditions and higher healthcare costs long term. Moreover, the absence of a comprehensive healthcare system may result in inequality, with disadvantaged populations being more vulnerable to health disparities.

A typical response to this issue provided by participants was:

*"They did not go to PH; they have own medication."*

*"We have a healthcare facility from Egypt; they brought medication, not rely on local PHC."*

The practical difficulties of delivering medical care in a transient and dynamic setting must also be taken into account. Since millions of pilgrims travel from one place to another during the Hajj, the needs for healthcare are always changing. One person made the observation,

*"We understand that Planning and coordination are essential since providing treatment in such a dynamic environment presents significant logistical hurdles."*

The provision of medical care during the Hajj is a complicated problem with many facets that offers difficulties. The Hajj presents healthcare providers with several concerns, including the possibility of infectious infections and logistical issues. In the end, resolving these issues is essential to protecting the health and welfare of the millions of pilgrims who go to the holy Hajj.

### Appropriateness of health services

Few of the participants reported inappropriate handling of their medication either by lack of aid tools such as ice bags or ice cubes for refrigeration of drugs, or lack of awareness resulting in exacerbation of their disorders which can lead to severe outcomes.

*"My insulin was corrupted"*

During the Hajj pilgrimage, many respondents reported experiencing transient respiratory infections. Interestingly, a significant number of these individuals chose not to seek treatment for their illnesses, attributing their symptoms to changing weather or exposure to air conditioning. This belief can have a direct impact on the use of health services during the Hajj.

The misconception that changing weather or exposure to air conditioning is the cause of transient respiratory infections reflects a misunderstanding of the underlying reasons for such illnesses. In reality, respiratory infections are primarily caused by viruses or bacteria that are transmitted through close contact with infected individuals. These infections can easily spread among the close quarters and large crowds typically found during the Hajj.

*"I got infected from my relative and did not take medication."*

*"One haji got an infection from a relative and she did not start taking treatment."*

*"The flu was caused by exposure to air conditioning."*

The appropriateness of medical care provided to pilgrims during the Hajj is crucial to their well-being. Ensuring the millions of pilgrims who take part in this yearly pilgrimage have access to proper and affordable healthcare services that prioritize emergency care and prevention measures is essential.

#### 4. Discussion

This study evaluated the healthcare facility accessibility during the MG of Hajj 2023. We revealed several critical challenges that require focused attention and strategic intervention. Understanding these challenges will provide a foundation for discussions on improving healthcare accessibility, approachability, acceptability, and appropriateness during pilgrimages. Approximately 2% of the pilgrims encountered difficulties in healthcare accessibility, suggesting that the existing infrastructure partially meets their basic needs. This finding aligns with observations from Hajj 2015 (10). However, targeted exploration of the specific challenges faced by 2.3% of respondents is crucial for improving accessibility.

In the second theme, approachability pertains to pilgrims with health needs who recognize accessible services that can positively influence their health. Factors, such as transparency, information on available treatments and services, and outreach initiatives play roles in enhancing or diminishing the approachability of healthcare services (11). Our study revealed that the sheer magnitude of the Hajj pilgrimage places immense pressure on the healthcare infrastructure, creating challenges in the approachability of health services.

Regarding the acceptability of the health services, our findings showed that language barriers emerged as a considerable impediment. The inability to effectively communicate symptoms and medical history may lead to misinterpretation, resulting in inadequate care. (12). Pilgrims expressing low confidence in services and avoiding seeking medical attention due to unclear accessibility underscore the importance of addressing language-related challenges. Initiatives, such as providing instructions in multiple languages, can significantly enhance the acceptability of healthcare services. (13). It is also essential to invest in interpreter services and provide multilingual healthcare professionals at key healthcare facilities during Hajj (14). These professionals can bridge the communication gap, ensure an accurate understanding of the patient's medical needs, and provide appropriate healthcare services.

The dependence on self-medication by certain pilgrims reveals shortcomings in the current healthcare infrastructure. Longer distances to seek medical care result in delays, discomfort, and potential exacerbation of health conditions. The decision to not seek treatment for respiratory infections hinders access to health services. By not receiving appropriate medical attention, individuals not only compromise their well-being but also put others at risk of contracting the infection (15). This can lead to further spread of illnesses within the crowded spaces of the Hajj, making it increasingly difficult for both pilgrims and health professionals to contain the outbreak.

We highlight instances of inappropriate handling of medications and misconceptions about the causes of respiratory infections, emphasizing the importance of ensuring the appropriateness of health services. Adequate training, awareness campaigns, and the provision of necessary tools and resources are essential components for improving the quality and appropriateness of healthcare services during Hajj (16).

In conclusion, the study underscores the multifaceted challenges in healthcare accessibility during the Hajj pilgrimage, ranging from language barriers and infrastructure gaps to inappropriate handling of medications. The findings emphasize the critical need for strategic interventions, such as investing in interpreter services, providing multilingual healthcare professionals, and enhancing overall infrastructure. Targeted improvements in approachability, acceptability, and appropriateness of healthcare services are essential to address the unique health needs of pilgrims. The study serves as a

comprehensive guide for policymakers, healthcare providers, and relevant authorities to collaboratively develop and implement effective measures, ensuring the safety and well-being of all participants during the Hajj pilgrimage.

## 5. Recommendations

Building upon the challenges identified in this study regarding healthcare accessibility during the Hajj pilgrimage, it is imperative to implement comprehensive strategies to address these issues. The following recommendations are proposed:

### 1. Strategic Placement of Healthcare Facilities:

To alleviate difficulties in healthcare accessibility, it is critical to strategically place clinics, hospitals, and medical staff along the Hajj route. Leveraging technology, a virtual map can be created to guide pilgrims to the nearest medical facility. This map, accessible through a website or mobile app, should provide real-time data on wait times, languages spoken, and available medical services. Augmenting the map with sound-based advice in various languages ensures that pilgrims, regardless of their linguistic backgrounds, can easily locate and access healthcare facilities.

### 2. Cultural Sensitivity in Approachability:

To enhance the approachability of healthcare services, it must be acceptable for pilgrims to seek medical attention, irrespective of their cultural background, language, or nationality. Healthcare facilities should employ multilingual staff and interpreters to facilitate effective communication. Additionally, technology, such as virtual translators and audio guidance tailored to specific languages, can bridge the communication gap, ensuring that pilgrims feel heard and understood when seeking medical assistance.

### 3. Diversified Medical Treatments and Resources Allocation:

Recognizing the diverse health needs of pilgrims from various geographical locations, it is crucial to offer a variety of medical treatments. Allocating resources equitably and ensuring that healthcare institutions possess the necessary tools, medicines, and medical personnel for diverse medical conditions is essential. Technology can play a role in arranging online consultations with specialized medical professionals, addressing the challenge of providing comprehensive healthcare during the pilgrimage.

By implementing these interconnected recommendations, including strategic placement of healthcare facilities, cultural sensitivity in approachability, and diversified medical treatments, we can make substantial progress in addressing the multifaceted challenges outlined in the discussion. This approach aligns with the study's emphasis on the need for targeted interventions and collaborative efforts to enhance healthcare services for the diverse population of pilgrims during the Hajj pilgrimage.

## References

1. Arbon P. The development of conceptual models for mass-gathering health. *Prehosp Disaster Med* [Internet]. 2004 [cited 2023 Nov 6];19(3):208–12. Available from: <https://pubmed.ncbi.nlm.nih.gov/15571196/>
2. WHO. Public Health for Mass Gatherings: Key Considerations. *World Heal Organ* [Internet]. 2015;82–94. Available from: [https://apps.who.int/iris/bitstream/handle/10665/162109/WHO\\_HSE\\_GCR\\_2015.5\\_eng.pdf;jsessionid=20CDEF66BA427C7DB54004047BD811E4?sequence=1](https://apps.who.int/iris/bitstream/handle/10665/162109/WHO_HSE_GCR_2015.5_eng.pdf;jsessionid=20CDEF66BA427C7DB54004047BD811E4?sequence=1)
3. Memish ZA, Steffen R, White P, Dar O, Azhar EI, Sharma A, et al. Mass gatherings medicine: public health issues arising from mass gathering religious and sporting events. *Lancet* [Internet]. 2019 May 18 [cited 2023 Nov 6];393(10185):2073–84. Available from: <http://www.thelancet.com/article/S014067361930501X/fulltext>

4. Ascoura IE. Impact of Pilgrimage (Hajj) on the Urban Growth of the Mecca. J Educ Soc Res. 2013 ;
5. Fulltext | The Role of Ambient Temperature and Plasma Osmolarity on Clinical Outcomes of Acute Myocardial Infarction Patients during Hajj [Internet]. [cited 2023 Oct 16]. Available from: <https://www.onlinescientificresearch.com/articles/the-role-of-ambient-temperature-and-plasma-osmolarity-on-clinical-outcomes-of-acute-myocardial-infarction-patients-during-hajj.html>
6. Memish ZA, Zumla A, Alhakeem RF, Assiri A, Turkestani A, Al Harby KD, et al. Lancet mass gatherings medicine 1 Hajj: infectious disease surveillance and control. *www.thelancet.com* [Internet]. 2014 [cited 2023 Nov 6];383. Available from: <https://www.gov.uk/>
7. Fouda A. A study to estimate the number of worshippers at the Grand Mosque. Government report. Umm Al-Qura Univ, Mecca, Kingdom of Saudi Arabia; 1998
8. Aldossari MR, Aljoudi A, Celentano D. Health issues in the Hajj pilgrimage: a literature review. *East Mediterr Health J* [Internet]. 2019 Oct 1 [cited 2023 Jun 8];25(10):744–53. Available from: <https://pubmed.ncbi.nlm.nih.gov/31774140/>
9. MOH News - MOH: More than 76,000 Male and Female Pilgrims Receive Medical Services in Makkah and Al-Madinah [Internet]. [cited 2023 Nov 6]. Available from: <https://www.moh.gov.sa/en/Ministry/MediaCenter/News/Pages/News-2023-06-25-001.aspx>
10. Mirza AA, Alsakkaf MA, Mohammed AA, Mirza AA, Elmorsy SA. Patterns of emergency department visits during Hajj period: Towards healthcare optimization in view of Saudi Arabia's vision 2030. *Pak J Med Sci*. 2019;35(3):647-52. doi: 12669/pjms.35.3.611. PubMed PMID: 31258569; PubMed Central PMCID: PMC6572959.
11. Levesque JF, Harris MF, Russell G. Patient-centred access to health care: conceptualising access at the interface of health systems and populations. *Int J Equity Health*. 2013;12:18. Epub 20130311. doi: 10.1186/1475-9276-12-18. PubMed PMID: 23496984; PubMed Central PMCID: PMC3610159.
12. Tiwary A, Rimal A, Paudyal B, Sigdel KR, Basnyat B. Poor communication by health care professionals may lead to life-threatening complications: examples from two case reports. *Wellcome Open Res*. 2019;4:7. Epub 20190122. doi: 10.12688/wellcomeopenres.15042.1. PubMed PMID: 31448336; PubMed Central PMCID: PMC6694717.
13. Molina RL, Kasper J. The power of language-concordant care: a call to action for medical schools. *BMC Med Educ*. 2019;19(1):378. Epub 20191106. doi: 10.1186/s12909-019-1807-4. PubMed PMID: 31690300; PubMed Central PMCID: PMC6833293.
14. Al Shamsi H, Almutairi AG, Al Mashrafi S, Al Kalbani T. Implications of Language Barriers for Healthcare: A Systematic Review. *Oman Med J*. 2020;35(2):e122. Epub 20200430. doi: 10.5001/omj.2020.40. PubMed PMID: 32411417; PubMed Central PMCID: PMC7201401.
15. Hughes RG. *Patient Safety and Quality: An Evidence-Based Handbook for Nurses*. . Agency for Healthcare Research and Quality (US) 2008.
16. De Luca G, Lisi, D., Martorana, M., & Siciliani, L. Does higher institutional quality improve the appropriateness of healthcare provision? *Journal of Public Economics*. 2021;194, 104356.



## Pattern, frequency of dental and oral issues, and the patient's satisfaction with the dental management and outcomes among pilgrims during the Umrah and Hajj

Fatma Mohamed Alkassimi

Basic Clinical Sciences, Faculty of Dental Medicine, Umm Al-Qura University

\*Corresponding author: E-mail (fmkassimi@uqu.edu.sa)

## نمط وتواتر مشاكل الأسنان والفم ورضا المريض عن خدمات الأسنان ونائج العلاجات المقدمة بين الزوار أثناء العمرة و الحج

فاطمة محمد القصيبي

العلوم الأساسية و السريرية كلية طب الأسنان، جامعة أم القرى

### المخلص

نظرًا لارتفاع معدل الانتشار والتأثير الاجتماعي لأمراض الأسنان/الفم، فإنها تعتبر قضية صحية عامة رئيسية على مستوى العالم. يتم إجراء هذه الدراسة لتقييم الحالة الصحية للفم وعوامل الخطر واحتياجات العلاج للحجاج. المواد والطرق: تستند الدراسة إلى سجلات الأسنان والفحص الفموي لعينة من الحجاج تم اختيارها عشوائياً وعددها ٣٢٠ مريض. سيتم تحليل البيانات التي تم جمعها لتحديد التركيبة السكانية للمرضى والتشخيص والعلاج والنتائج. كما سيتم توزيع استبيان باللغتين الإنكليزية والعربية على الحجاج خلال زيارتهم لعيادات طب الأسنان. وسيتم استخدام أقسام مختلفة وسيتم استخدامه لجمع معلومات حول تصور المرضى للعلاج والرضا عن الخدمات. النتائج: سيتم مقارنة الحالة الصحية الفموية للحجاج بعامة الناس. ونتيجة لذلك، سيتم الكشف عن أوجه التشابه والاختلاف بين كلا المجموعتين. الاستنتاج: قد يساعد تقييم الحالة الصحية للحجاج وعوامل الخطر وتقييم تجاربهم في مواعيد الأسنان، في تحسين خدمات ومرافق طب الأسنان خلال الحج والعمرة.

### Abstract

Due to the high prevalence and social impact of dental/oral diseases, it is considered a major public health issue globally. This study is conducted to assess the oral health status, risk factors, and treatment needs of the pilgrims. Materials and methods: The study is based on the dental records and oral examination of a randomly chosen 320 samples of pilgrims. The collected data will be analyzed to determine the patients' demographics, diagnosis, treatment, and outcomes. Also, a questionnaire in both English and Arabic will be distributed to pilgrims during their visits to the dental clinics. It will be composed of various sections and will be used to gather information about the patient's perception of the treatment and satisfaction with the services. Results: The oral health status of the pilgrims will be compared to the general people. As a result, the similarities and differences among both populations will be disclosed. Conclusion: The assessment of the pilgrims' oral health status, and risk factors and evaluating their dental care experiences may help in improving the dental services and facilities during the Umrah and Hajj.

**Keywords:** Pilgrims, Umrah, Hajj, Dental disorders, Oral issues, Patient's Satisfaction.

## Introduction

Individuals may encounter certain risk factors that can have negative impacts on their oral and dental health. These factors include diet, psychological disorders, behaviors, socioeconomic status, health conditions, and access to dental services can all be considered risk factors.

Caries and periodontal diseases and several other oral conditions show a very high prevalence among the global population. In addition, barriers to dental services, malpractice, and medication misuse all are major issues that have been discussed in many national and international articles.

Since no previous study evaluates the previous aspects of the pilgrims during the Umrah and Hajj. The following references were reviewed to compare the dental data of the other populations with the pilgrims to provide a better understanding of the pilgrims' dental concerns and requirements.

## Review of literature

In dental disorders, diet plays a major role. It has been documented that, sugars, especially sucrose, are the primary cause of caries. However, the quantity and frequency of consumption of sugars are important factors in determining their etiology. (Sheiham, 2001). Individuals who consume more than four times a day of extrinsic sugars are more prone to dental caries. The relationship between extrinsic sugars and caries has been established, suggesting that higher levels of these substances increase the risk of tooth decay (Sheiham, 2001). One of the most important factors that can prevent dental caries is the presence of fluoride in toothpaste. However, even though there is currently a wide range of products that contain fluoride, it does not seem that they can provide a significant benefit to the majority of people. This is why people must reduce their daily intake of sugar. (Sheiham, 2001).

Dental erosion is another significant dental problem. It has been reported that the increasing rates of dental erosion are believed to be due to the presence of acids in various food and beverage products. These findings support that diet strongly contributes to the pathogenesis of several dental disorders. (Sheiham, 2001).

Several studies reported the connection between the psychological status and the dental and oral health conditions. Pilgrimage may experience high levels of stress or anxiety as they are away from their hometown and families.

The most common oral health issues that affect psychiatric patients are caries, periodontal diseases, and dental erosion. Significantly, the advanced stage of these conditions can lead to tooth loss. (Cormac & Jenkins, 1999). A study reported that Individuals suffering from psychiatric illnesses may have poor oral health due to their lifestyle and lack of access to dental care. (Kisely, Baghaie, Lalloo, & Johnson, 2015; Kisely, Baghaie, Lalloo, et al., 2015).

Another study found that depression was associated with higher Recurrent aphthous stomatitis. It also revealed that anxiety was related to the condition. (Yang et al., 2018). The study also found that depression was associated with Burning mouth syndrome (BMS) and Oral lichen planus (OLP). This conclusion is similar to previous literature, which suggests that psychological stress and anxiety are related to BMS and OLP. (Gavic et al., 2014; Ivanovski et al., 2005; Zadik et al., 2012).

Also, a study conducted on female dental students in Saudi Arabia revealed that about 14% of the students had Recurrent Aphthous Stomatitis (RAS). Around 70% indicated that the ulcer could be linked to certain factors. Stress was the main cause of the issue, with depression and anxiety being the other ones. In the ( Hospital Anxiety and Depression scale ) HAD scale, around 65% had depression and 88% had anxiety; all patients with depression had anxiety. (Ajmal et al., 2018).

The eosinophilic ulcer is characterized by a raised and indurated mass commonly referred to as an ulcer. Specialists believe that trauma, such as accidental bites or repeated thrusting against a fractured or sharp tooth, can lead to this disease. However, its exact cause is not known. Similarly, to the previous oral conditions, eosinophilic ulcers could also be triggered by stress-induced neuroimmunological factors. (Abdullah, 2011; Hirshberg et al., 2006; Horie et al., 1999; Ribeiro et al., 2011; Segura & Pujol, 2008; Segura et al., 2006; Vasconcelos et al., 2011; Vélez et al., 1997).

Another study supported the impact of psychological status on the oral health condition. For example, the group Pemphigus comprises a variety of autoimmune bullous disorders that manifest in various intraepithelial lesions, including the skin and mucous membranes. The most common form of this group is Pemphigus vulgaris (PV), which is a prototypical organ-specific human autoimmune disorder that has a poor prognosis if left untreated. (Ruocco et al., 2013). The various factors that can cause acantholysis are many and come from the environment. Some of these include viral infections, diet, physical agents, and drug intake. Some of these factors that can trigger acantholysis are endogenous, such as emotional stress or hormonal disorders. (Cremniter et al., 1998; Morell-Dubois et al., 2008).

It is well established that regular tooth brushing helps to prevent tooth decay and gum disease by reducing the number of bacteria and plaque around the teeth and gingiva. Individuals who claim that they only brush their teeth occasionally are more prone to developing new cavities, or lesions than those who do so more frequently. The effects of this habit are more pronounced in the case of deciduous teeth. (Kumar et al., 2016).

Being socioeconomically disadvantaged throughout childhood, middle, and later in life was associated with poor oral health in older adults. These findings suggest that different socioeconomic factors can affect the oral health of older individuals. The relationship between socioeconomic status and oral health was explained by different life-course models. The middle-age period was associated with heightened sensitivity to exposure to various factors. (Ramsay et al., 2018).

To compare the most common lesions in the pilgrimage to the general population, knowing the most frequent oral lesions and dental disorders in the global population is required. The following studies summarized these common diseases.

Dental caries is a global public health issue that cannot be neglected. (Al Agili, 2013). All socioeconomic strata are affected by this condition, which affects aspects of a person's life, including school attendance, eating habits, and growth. It can also have psychological effects on a patient's performance. (Teshome et al., 2021). In developing nations, dental caries are still untreated due to the lack of access to proper services and the scarcity of dentists. Due to the increasing awareness about oral hygiene and the availability of advanced dental facilities, the prevalence rate of dental caries has decreased in developed nations. (Teshome et al., 2021). Caries estimates in the present study were lower than those in other studies that were carried out in Gulf nations (64.7%), Brazil (72.9%), China (67%), and Kosovo (72.80%). The subgroup analysis revealed that dental caries prevalence was highest in Eritrea at 65.2%. It was followed by Sudan at 57.8% and Tanzania at 30.7%. In low-income countries, the cost of treatment exceeds the total cost of child health care. The disparity in the quality of dental services between countries within a region is believed to be caused by the varying socioeconomic status and dental facilities of each country. (Teshome et al., 2021).

A second major disorder known as periodontal disease, which includes conditions such as periodontitis and gingivitis, affects the tissues surrounding and supporting the teeth. The Global Burden of Disease Study (2016) reported that periodontal disease is regarded as the 11th most common condition worldwide, with prevalence varying from 20% to 50% in various parts of the world. (Carapetis & Dadi, 2017; Sanz, 2010). This condition can lead to tooth loss and affect various aspects of one's life, such as self-confidence and mastication. (Reynolds & Duane, 2018; Tonetti, Jepsen, et al.,



2017). The rise of periodontal disease is anticipated to be driven by the growth in the aging population and the increase in the retention of natural teeth. (Tonetti, Bottenberg, et al., 2017).

This study revealed that one of the most common oral diseases that can affect a person's oral cavity is recurrent aphthous stomatitis. Apart from this, other conditions such as recurrent herpes simplex labialis and stomatitis are also known to cause oral ulcers. About 3% of the population can experience benign migratory glossitis. Although this condition doesn't usually cause symptoms, some individuals experience burning sensations or food sensitivity. (Randall et al., 2022). Up to 2% of individuals will develop oral lichen planus, which can cause ulcerations, reticulations, or oral erosions. (Randall et al., 2022). Aging male patients are more prone to having hairy tongues, which are linked to poor oral hygiene, tobacco and alcohol use, and a low-fiber diet. Alcohol and tobacco consumption can result in changes in the mucosal lining, which can lead to erythroplakia and leukoplakia. These conditions can lead to precancerous changes and an increased risk of developing squamous cell carcinoma. (Randall et al., 2022). The mandible and the maxillary tori are examples of cortical outgrowths that do not need treatment. Also, oral candidiasis is a common oral condition, especially in immunocompromised individuals and patients with poor oral hygiene. A group of benign lesions that includes mucocele and traumatic fibromas are common lesions that usually are treated by excision. (Randall et al., 2022). In addition to amalgam tattoos, Pyogenic Granuloma, Oral melanoma, and Squamous Cell Papilloma (SCP) were mentioned in another study. (Zahid et al., 2022).

In contrast to the previous study, this study which was conducted among older Danes society revealed multiple different common oral mucosal lesions. (Lyng Pedersen et al., 2015). The highest frequently detected oral mucosal lesions included lingual varicose veins, denture stomatitis, fissured tongue, and frictional keratosis. (Lyng Pedersen et al., 2015). Local environmental changes were associated with the development of these lesions. They were not related to the gender or age of the subjects. The results indicate that the development of tongue lesions, especially the fissured and atrophy of the tongue papillae, can be clinical indicators of the hypofunction of the salivary gland and xerostomia caused by medications. (Lyng Pedersen et al., 2015). Furthermore, Oral candidiasis and Candida colonization are other risk factors for concern in older individuals with polypharmacy and comorbidities. (Lyng Pedersen et al., 2015).

Dental mistakes are among the most common medical errors that should be evaluated. The most common adverse events that happen in this series are those related to oral surgery, endodontics, and implantology. (Perea-Pérez et al., 2014). A significant number of patients who experienced an adverse event during their dentistry treatment required hospitalization. The number of adverse events that were treated and resolved at the center was only 3.4%. (Perea-Pérez et al., 2014). Although tooth loss is the most common adverse event, other serious complications can also occur. These include chronic sinus problems, nerve damage, bone loss, and even death. While most of the accidents and complications studied were unforeseeable (55.7%), a significant percentage were caused by preventable and foreseeable errors (44.3%). (Perea-Pérez et al., 2014). A pilot study conducted, of nearly 400 U.S.-based, ADA member dentists, revealed that almost half of all US-based dentists are worried about a perceived dental error in the last six months. (Yansane et al., 2021).

The results of the study revealed that among the dentists, one in seven were highly burned out, while around one in three were highly engaged. Burnout was associated with a lower level of work engagement. Self-reported dental mistakes were associated with elevated burnout risks. The work-related error rate did not change regardless of the level of engagement. The exact cause of work-related errors is still unclear. Further studies are required to analyze the factors that influence this issue at the system and individual levels. (Yansane et al., 2021).

Several medications are usually prescribed globally by dentists. Most of the medicines that dentists prescribe are antibiotics. Since most human orofacial infections are caused by odontogenic factors, dentists have become more involved in prescribing antibiotics. (Laskin & Laskin, 1985). Dentists usually prescribe around 7% to 11% of all types of antibiotics, some of these include macrolides, tetracyclines, beta-lactams, clindamycin, and metronidazole. (Cleveland & Kohn, 1998).

In the UK, dentists dispensed 7% of all community antibiotic prescriptions. According to the National Center for Disease Control and Prevention, around one-third of all outpatient antibiotic prescriptions are unnecessary. (Sweeney et al., 2004). Administering antibiotics may result in various adverse effects, including anaphylactic shock, gastrointestinal issues, and the development of resistance. (Dar-Odeh et al., 2010). The rise in resistance issues that have been identified in recent years may be the result of the misuse of certain broad-spectrum antibiotics, such as fluoroquinolones and cephalosporins. (Wise et al., 1998).

In emergencies and clinical settings, opioids are frequently utilized to manage short-term pain associated with certain dental procedures. (Hersh et al., 2011; Moore & Hersh, 2013). A small number of dental patients had previous prescriptions for opioid medications, which is a contributing factor to the abuse, misuse, and diversion of these drugs. (McCauley et al., 2016).

COX-2 inhibitors and the nonsteroidal drugs known as Nonsteroidal anti-inflammatory drugs (NSAIDs) are widely used for their ability to reduce inflammation and pain. (Nagi et al., 2015). These drugs are commonly prescribed in dentistry to manage swelling and pain, including acute dental pain and chronic orofacial pain, as adjuncts to the treatment of periodontal disease, and to reduce edema following surgical procedures is well documented. (Nagi et al., 2015).

The prolonged use of nonselective nonsteroidal anti-inflammatory drugs (NSAIDs) may increase the risk of developing gastrointestinal symptoms, such as nausea, vomiting, and mild or severe gastric issues, including perforation or bleeding. Although there are fewer GI side effects of selective cox-2 drugs, their use in dentistry has been restricted due to cardiovascular reactions. (Nagi et al., 2015). One of the most common oral medical concerns is the effects of NSAIDs on mucosal lesions. This can prolong the bleeding time during various dental procedures. (Nagi et al., 2015).

### **Aims and objectives**

The objective of the study is to analyze the patterns and frequency of dental issues and oral diseases among pilgrims during the Hajj and Umrah. It also aims to determine the accessibility of the services and the outcomes of the treatment for the visitors.

### **Research design and method**

A cross-sectional study will be based on data gained from pilgrims visiting the dental services during the Hajj and Umrah. The study duration is 6 months, from February 2024 to August 2024 which includes the hajj days. Written consent will be obtained from every participant in the study. The inclusion criteria are a pilgrim with a dental problem or oral disease. The exclusion criteria are a non-pilgrim and a pilgrim with healthy teeth and oral tissues.

The sample size will be determined by computing a power analysis based on the number of items in the main component analysis. The study's power will be set at 0.80 and  $\beta$  at 0.20. The sample could have been as many as 2:1=30:1 or 10:1. A random sample of 320 subjects was considered sufficient to carry out the study, with a 20% non-response rate. (Osborne & Costello, 2019). Stratified random sampling will be utilized for the study. The participants will be categorized into five age groups according to the WHO's Basic Oral Health Survey guidelines 1997 and also categorized by gender.

(Organization, 2013). The study will be composed of two main sections: the first one will be based on the dental records and oral examination. The second section is a questionnaire that will be distributed to pilgrims during their visits to the dental clinics. It will be composed of various sections and will be used to gather information about the patient's perception of the treatment and satisfaction with the services.

The first part of the study: A skilled examiner will assess all participants under natural light using the WHO periodontal probe and plane mouth mirror. Each examination will last for around 10 to 15 minutes. The exams were carried out according to WHO guidelines. To test the reliability of the examiner, 25 participants will undergo duplicate examinations. The pilot study will be conducted before the main study, which will involve 25 participants. It will analyze the effects of training and calibration on the Intra-Examiner reproducibility. The results of the evaluation will be then analyzed by the Cohen Kappa statistical model. This measure will analyze the prevalence of oral lesions, dental caries, and periodontal disease. (Singh et al., 2020).

The second part of the study: A questionnaire will be distributed to both non-Arab and Arab patients using Arabic and English formats. Professional translation websites will be used to translate the questionnaire for the patients who do not speak Arabic or English and communicate with them.

The questionnaire will be developed after reviewing previous studies (Bamise et al., 2008; Sakalauskiene et al., 2005) and composed of several sections. The questionnaire will be evaluated by experienced faculty members to see if it is practical and relevant to the study participants and to evaluate the validity of the instrument. The Cronbach alpha will be calculated after the questionnaire's reliability is evaluated. (Balhaddad et al., 2018).

Furthermore, the questionnaire will be administered to 25 subjects to ensure the correct comprehension of the questions. The questionnaire covered the subjects' personal information and the details of their visits to dental clinics. Also, the questionnaire will include the WHO oral health assessment form which is widely used by dentists. (Organization, 2013).

It contains various sections, such as survey identification, additional-oral examination, intraoral mucosa, dental fluorosis, loss of attachment, periodontal index, and treatment needs. Also, the oral hygiene practices and the associated treatment barriers will be assessed. The Kuppuswamy's socioeconomic status scale measures various aspects of a family's socioeconomic well-being, such as income, education, and occupation will be included as well. It can be divided into four subclasses (upper, middle, lower, and upper) and is used for analyzing the overall situation of a family. (Ghosh & Ghosh, 2009; Nepal, 2017).

The last part of the questionnaire will focus on the patient's satisfaction with the coordination and convenience of their appointments, the clinic's facilities, and lastly the interaction and communication between the patient and the dentist. The Likert scale will be used to give people various choices, such as disagree, neutral, agree, and strongly agree. (Balhaddad et al., 2018).

The obtained data will be entered into a Microsoft Excel Sheet, and then the analysis will be conducted using the Statistical Package for Social Science (SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp).

The frequency and mean scores of each item in a questionnaire will then be calculated.

The relationship between the various factors will be evaluated using the Mann-Whitney U test to compare the mean DMFT/dft. In addition, the standard deviations and mean values of DMFT will be calculated using descriptive statistics.

A p-value < 0.05 indicates statistically significant. (Singh et al., 2020).

## Results

The literature revealed that dental caries and periodontal diseases are common among global residents. It also showed that many risk factors are implicated in oral health status. Also, the studies referred to the importance of accurate prescriptions and medications in the dental field. Finally, the malpractice, dental errors, accessibility, and patient satisfaction during dental visits.

Our collected data will target the pilgrims only. The results will include the frequency, and pattern of the dental issues, and oral conditions and reveal the accessibility to the dental services or any other obstacles. The data will capture the gender, age, ethnicity, diagnosis, treatment, outcomes, and described medications. Finally, the patient's satisfaction with the dental services.

## Conclusion

This study will describe the pattern, and frequency of dental and oral issues and evaluate the provided dental services during the Hajj and Umrah. In addition, the study will find out the most common dental diagnosis/oral condition, the most common management, and medications prescribed to pilgrims. The results of the study may help in providing the best possible dental care services to pilgrims.

## Ethical considerations

All research subjects are free to participate voluntarily without any pressure or coercion. Participants may withdraw from the study at any time, without any obligation to continue.

Informed consent will be taken. Potential participants will be given all the necessary information about the study so they can make informed decisions. This includes the benefits, funding, institutional approval, and risks.

Confidentiality: all the participants' data will be safeguarded as long as we store or use them.

Only the individuals approved by the Institutional Review Board (IRB) can access the study's data. We will ensure that everyone follows the institution's privacy policies.

Potential for harm: There is no source of harm, however, if any exist, we will find concrete ways to mitigate them.

All the necessary steps will be taken to avoid plagiarism and research misconduct.

## Funding

The development of the proposal was not funded.

## Conflicts of interest

There are no conflicts of interest.

## References

- Abdullah, B. H. (2011). Traumatic ulcerative granuloma with stromal eosinophilia (a clinicopathological study of 18 cases). *J Bagh Coll Dent*, 23, 59-64 .
- Ajmal, M., Ibrahim, L., Mohammed, N., & Al-Qarni, H. (2018). Prevalence and psychological stress in recurrent aphthous stomatitis among female dental students in Saudi Arabia. *Clujul medical*, 91(2), 216 .
- Al Agili, D. E. (2013). A systematic review of population-based dental caries studies among children in Saudi Arabia. *The Saudi dental journal*, 25(1), 3-11 .

- Balhaddad, A. A., Alshammari, A., AlqADI, A., & Nazir, M. A. (2018). Patient Satisfaction with Dental Services and Associated Factors in a Saudi Dental Institution. *Journal of Clinical & Diagnostic Research*, 12 .(12)
- Bamise, C., Bada, T., Bamise, F., & Ogunbodede, E. (2008). Dental care utilization and satisfaction of residential university students. *Libyan journal of medicine*, 3(3), 1-6 .
- Carapetis, J. R., & Dadi, A. F. (2017). Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet*, 390(10100), 1211-1259 .
- Cleveland, J., & Kohn, W. (1998). Antimicrobial resistance and dental care: a CDC perspective. *Dent Abstr* ,
- Cormac, I., & Jenkins, P. (1999). Understanding the importance of oral health in psychiatric patients. *Advances in psychiatric treatment*, 5(1), 53-60 .
- Cremniter, D., Baudin, M., Roujeau, J.-C., Prost, C., Consoli, S. G., Francés, C., & Chosidow, O. (1998). Stressful life events as potential triggers of pemphigus. *Archives of dermatology*, 134(11), 1486-1487 .
- Dar-Odeh, N. S., Abu-Hammad, O. A., Al-Omiri, M. K., Khraisat, A. S., & Shehabi, A. A. (2010). Antibiotic prescribing practices by dentists: a review. *Therapeutics and clinical risk management*, 6, 301 .
- Gavic, L., Cigic, L., Biocina Lukenda, D., Gruden, V., & Gruden Pokupec, J. S. (2014). The role of anxiety, depression, and psychological stress on the clinical status of recurrent aphthous stomatitis and oral lichen planus. *Journal of Oral Pathology & Medicine*, 43(6), 410-417 .
- Ghosh, A., & Ghosh, T. (2009). Modification of Kuppaswamy's Socioeconomic Status Scale in context to Nepal. *Indian Pediatr* .
- Hersh, E. V., Kane, W. T., O'Neil, M. G., Kenna, G. A., Katz, N. P., Golubic, S., & Moore, P. A. (2011). Prescribing recommendations for the treatment of acute pain in dentistry. *Compendium of Continuing Education in Dentistry (15488578)*, 32 .(3)
- Hirshberg, A., Amariglio, N., Akhris, S., Yahalom, R., Rosenbaum, H., Okon, E., & Kaplan, I. (2006). Traumatic ulcerative granuloma with stromal eosinophilia: a reactive lesion of the oral mucosa. *American journal of clinical pathology*, 126(4), 522-529 .
- Horie, N., Shimoyama, T., Kato, T., & Ide, F. (1999). Eosinophilic ulcer of the tongue: A case report with immunohistochemical study. *Oral medicine & pathology*, 4(1), 25-29 .
- Ivanovski, K., Nakova, M., Warburton, G., Pesevska, S., Filipovska, A., Nares, S., Nunn, M. E., Angelova, D., & Angelov, N. (2005). Psychological profile in oral lichen planus. *Journal of clinical periodontology*, 32(10), 1034-1040 .
- Kisely, S., Baghaie, H., Laloo, R., & Johnson, N. W. (2015). Association between poor oral health and eating disorders: systematic review and meta-analysis. *The British Journal of Psychiatry*, 207(4), 299-305 .
- Kisely, S., Baghaie, H., Laloo, R., Siskind, D., & Johnson, N. W. (2015). A systematic review and meta-analysis of the association between poor oral health and severe mental illness. *Psychosomatic medicine*, 77(1), 83-92 .
- Kumar, S., Tadakamadla, J., & Johnson, N. (2016). Effect of toothbrushing frequency on incidence and increment of dental caries: a systematic review and meta-analysis. *Journal of dental research*, 95(11), 1230-1236 .
- Laskin, D., & Laskin, J. (1985). Odontogenic infections of the head and neck. *Oral and maxillofacial surgery*. St Louis: Mosby, 219-252 .
- Lyng Pedersen, A., Nauntofte, B., Smidt, D., & Torpet, L. (2015). Oral mucosal lesions in older people: relation to salivary secretion, systemic diseases and medications. *Oral diseases*, 21(6), 721-729 .
- McCauley, J. L., Hyer, J. M., Ramakrishnan, V. R., Leite, R., Melvin, C. L., Fillingim, R. B., Frick, C., & Brady, K. T. (2016). Dental opioid prescribing and multiple opioid prescriptions among dental patients: administrative data from the South Carolina prescription drug monitoring program. *The Journal of the American Dental Association*, 147(7), 537-544 .
- Moore, P. A., & Hersh, E. V. (2013). Combining ibuprofen and acetaminophen for acute pain management after third-molar extractions: translating clinical research to dental practice. *The Journal of the American Dental Association*, 144(8), 898-908 .
- Morell-Dubois, S., Carpentier, O., Cottencin, O., Queyrel, V., Hachulla, E., Hatron, P.-Y., & Delaporte, E. (2008). Stressful life events and pemphigus. *Dermatology*, 216(2), 104-108 .

- Nagi, R., Devi, B. Y., Rakesh, N., Reddy, S. S., & Patil, D. J. (2015). Clinical implications of prescribing nonsteroidal anti-inflammatory drugs in oral health care—a review. *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology*, 119(3), 264-271 .
- Nepal, R. (2017). Nepal Rastra Bank. Recent macroeconomic and financial situation. Research Department, Statistics Division, Kathmandu, Nepal. 2017. In.
- Organization, W. H. (2013). Oral health surveys: basic methods. World Health Organization .
- Osborne, J. W., & Costello, A. B. (2019). Sample size and subject to item ratio in principal components analysis. *Practical Assessment, Research, and Evaluation*, 9(1), 11 .
- Perea-Pérez, B., Labajo-González, E., Santiago-Sáez, A., Albarrán-Juan, E., & Villa-Vigil, A. (2014). Analysis of 415 adverse events in dental practice in Spain from 2000 to 2010. *Medicina oral, patología oral y cirugía bucal*, 19(5), e500 .
- Ramsay, S. E., Papachristou, E., Watt, R. G., Lennon, L. T., Papacosta, A. O., Whincup, P. H., & Wannamethee, S. G. (2018). Socioeconomic disadvantage across the life-course and oral health in older age: findings from a longitudinal study of older British men. *Journal of Public Health*, 40(4), e423-e430 .
- Randall, D. A., Westmark, N. L. W., & Neville, B. W. (2022). Common Oral Lesions. *American Family Physician*, 105(4), 369-376 .
- Reynolds, I., & Duane, B. (2018). Periodontal disease has an impact on patients' quality of life. *Evidence-based dentistry*, 19(1), 14-15 .
- Ribeiro, A. L. R., de Oliveira Mendes, F. R., Alves, S. d. M., & Pinheiro, J. d. J. V. (2011). Eosinophilic ulcer: the role of stress-induced psychoneuroimmunologic factors. *Oral and maxillofacial surgery*, 15, 179-182 .
- Ruocco, V., Ruocco, E., Schiavo, A. L., Brunetti, G., Guerrero, L. P., & Wolf, R. (2013). Pemphigus: etiology, pathogenesis, and inducing or triggering factors: facts and controversies. *Clinics in dermatology*, 31(4), 374-381 .
- Sakalauskiene, Z., Maciulskiene, V., & Sertvytyte, A. (2005). Testing of the questionnaire on dental care satisfaction in a sample of adult patients visiting dental clinics at Faculty of Odontology, Kaunas University of Medicine. A pilot study. *Stomatologija*, 7(3), 84-89 .
- Sanz, M. (2010). European workshop in periodontal health and cardiovascular disease. In (Vol. 12, pp. B2-B2): Oxford University Press.
- Segura, S., & Pujol, R. (2008). Eosinophilic ulcer of the oral mucosa: a distinct entity or a non-specific reactive pattern? *Oral diseases*, 14(4), 287-295 .
- Segura, S., Romero, D., Mascaro Jr, J., Colomo, L., Ferrando, J., & Estrach, T. (2006). Eosinophilic ulcer of the oral mucosa: another histological simulator of CD30+ lymphoproliferative disorders. *British Journal of Dermatology*, 155(2), 460-463 .
- Sheiham, A. (2001). Dietary effects on dental diseases. *Public health nutrition*, 4(2b), 569-591 .
- Singh, A., Shrestha, A., Bhagat, T., & Baral, D. (2020). Assessment of oral health status and treatment needs among people of Foklyan area, Dharan, Nepal. *BMC Oral Health*, 20(1), 1-8 .
- Sweeney, L. C., Dave, J., Chambers, P. A., & Heritage, J. (2004). Antibiotic resistance in general dental practice—a cause for concern? *Journal of Antimicrobial chemotherapy*, 53(4), 567-576 .
- Teshome, A., Mucho, A., & Girma, B. (2021). Prevalence of dental caries and associated factors in East Africa, 2000–2020: systematic review and meta-analysis. *Frontiers in Public Health*, 9, 645091 .
- Tonetti, M. S., Bottenberg, P., Conrads, G., Eickholz, P., Heasman, P., Huysmans, M. C., López, R., Madianos, P., Müller, F., & Needleman, I. (2017). Dental caries and periodontal diseases in the ageing population: call to action to protect and enhance oral health and well-being as an essential component of healthy ageing—Consensus report of group 4 of the joint EFP/ORCA workshop on the boundaries between caries and periodontal diseases. *Journal of clinical periodontology*, 44, S135-S144 .
- Tonetti, M. S., Jepsen, S., Jin, L., & Otomo-Corgel, J. (2017). Impact of the global burden of periodontal diseases on health, nutrition and wellbeing of mankind: A call for global action. *Journal of clinical periodontology*, 44(5), 456-462 .
- Vasconcelos, M. G., de Souza, L. B., da Silveira, É. J. D., de Medeiros, A. M. C., de Vasconcelos Carvalho, M., & Queiroz, L. M. G. (2011). Eosinophilic ulcer of the lateral tongue: case report. *RSBO Revista Sul-Brasileira de Odontologia*, 8(4), 459-463 .

- Vélez, A., Alamillos, F. J., Dean, A., Rodas, J., & Acosta, A. (1997). Eosinophilic ulcer of the oral mucosa: report of a recurrent case on the tongue. *Clinical and experimental dermatology*, 22(3), 154-156 .
- Wise, R., Hart, T., Cars, O., Streulens, M., Helmuth, R., Huovinen, P., & Sprenger, M. (1998). Antimicrobial resistance. In (Vol. 317, pp. 609-610): British Medical Journal Publishing Group.
- Yang, C., Liu, L., Shi, H., & Zhang, Y. (2018). Psychological problems and quality of life of patients with oral mucosal diseases: a preliminary study in Chinese population. *BMC Oral Health*, 18, 1-7 .
- Yansane, A., Tokede, O., Walji, M., Obadan-Udoh, E., Riedy, C., White, J., & Kalenderian, E. (2021). Burnout, engagement, and dental errors among US dentists. *Journal of Patient Safety*, 17(8), e1050-e1056 .
- Zadik, Y., Levin, L., Shmuly, T., Sandler, V., & Tarrasch, R. (2012). Recurrent aphthous stomatitis: stress, trait anger and anxiety of patients. *Journal of the California Dental Association*, 40(11), 879-883 .
- Zahid, E., Bhatti, O., Zahid, M. A., & Stubbs, M. (2022). Overview of common oral lesions. *Malaysian family physician: the official journal of the Academy of Family Physicians of Malaysia*, 17(3), 9 .



## Innovative Approaches to Cardiac Care: Understanding the Significance of King Abdullah Medical City's Hajj Season Strategies on Door-to-Balloon Time for Primary Percutaneous Coronary Intervention

Ebtisam A. elhihi<sup>\*1</sup>, Faisal A. Alasmari<sup>1</sup>, Omar K. Abdel Rahman<sup>2</sup>, Fahad T. Almoallad<sup>3</sup>, Reem A. alsalhi<sup>3</sup>, Shuruq

F. alosaimi<sup>3</sup>, Faisal M. alhazmi<sup>3</sup>, Marwan S. Hawsawei<sup>4</sup>, Ziyad A. Alasmari<sup>5</sup>

1 -Nursing Research and evidence-based practice Department, King Abdullah Medical City, 2 -Cardiac care unit, King Abdullah Medical City, 3 -Cath lab, King Abdullah Medical City, 4 -Nursing administration, King Abdullah Medical City, 5- Day care department, King Abdullah medical city.

\*Corresponding author: E-mail (elhihi.e@kamc.med.sa)

## مناهج مبتكرة للعناية بالقلب: فهم أهمية استراتيجيات موسم الحج في مدينة الملك عبد الله الطبية بشأن الوقت من الباب إلى البالون للتدخل التاجي الأولي عن طريق الجلد

ابتسام الهيبي<sup>\*1</sup>, فيصل عبد الرحمن الأسمرى<sup>1</sup>, عمر خالد عبد الرحمن<sup>2</sup>, فهد المولد<sup>3</sup>, ريم الصالحي<sup>3</sup>, شروق العصبى<sup>3</sup>, فيصل محمد الحازمي<sup>3</sup>, مروان سعيد هوساوي<sup>4</sup>, زياد الأسمرى<sup>5</sup>

1- قسم أبحاث التمريض والممارسات المبنية على الأدلة، مدينة الملك عبد الله الطبية، 2- وحدة رعاية القلب، مدينة الملك عبد الله الطبية، 3- قسرة القلب، مدينة الملك عبد الله الطبية، 4- إدارة التمريض، مدينة الملك عبد الله الطبية، 5- قسم عمليات اليوم الواحد، مدينة الملك عبد الله الطبية.

### المخلص

الخلفية: من المهم تقليل وقت من الباب إلى البالون، خاصة في المستشفيات حيث يتم إجراء التدخل التاجي المبكر خلال 90 دقيقة. الهدف: كان الغرض من هذه الدراسة هو تحديد تأثير استراتيجيات مدينة الملك عبد الله الطبية على وقت البالون للمرضى الذين يعانون من STEMI.

الطرق: تم إجراء بحث رصدي مستقبلي في مدينة الملك عبد الله الطبية. تم تضمين 67 مريضاً من الذين يحتاجون التدخل التاجي الأولي عن طريق الجلد. تم جمع البيانات في حج 2023 من خلال الملاحظة المباشرة باستخدام قائمة مرجعية تضمنت جزأين: الجزء الأول: الخصائص الديموغرافية للمرضى؛ والجزء الثاني: الفترات الزمنية ذات الصلة.

النتائج: لوحظ أن متوسط الوقت الإجمالي من الباب إلى البالون كان 68 دقيقة لمرضى القبول المباشر و100 دقيقة للمرضى المنقولين بين المستشفيات، مع قيمة P ذات دلالة إحصائية تبلغ 0.001. لا توجد علاقة ذات دلالة إحصائية بين إجمالي الوقت من الباب إلى البالون لمرضى القبول المباشر والمرضى المنقولين بين المستشفيات ومدة الإقامة،  $E = 0.42$ ، أو إجمالي الوقت من الباب إلى البالون لمرضى القبول المباشر والمرضى المنقولين بين المستشفيات والوفيات في المستشفيات،  $E = 0.39$ .

الخلاصة: حققت مدينة الملك عبد الله الطبية معياراً عالمياً في زمن الوصول من الباب إلى البالون لمرضى احتشاء عضلة القلب النصفى (STEMI) الذين يزورون المستشفى لإجراء التدخل التاجي عن طريق الجلد خلال موسم الحج.



## Abstract

**Background:** It is important to reduce the door to balloon time, especially in hospitals where early coronary intervention is carried out within 90 minutes. **Aim:** The purpose of this study was to determine the impact of King Abdullah Medical City's strategies on balloon time for patients with STEMI.

**Methods:** Prospective observational research was conducted in King Abdullah Medical City. 67 patients who had a primary percutaneous coronary intervention were included. Data was collected in Hajj 2023 through direct observation using a checklist that included two parts: Part I: patients' demographic characteristics; and Part II: relevant time intervals.

**Results:** It was noted that the overall median door-to-balloon time was 68 minutes for direct admission patients and 100 minutes for interhospital transferred patients, with a statistically significant P value of 0.001. There is no statistically significant relationship between the total door-to-balloon time of direct admission patients and interhospital transferred patients and length of stay,  $p = 0.42$ , or the total door-to-balloon time of direct admission patients and interhospital transferred patients and hospital mortality,  $p = 0.39$ .

**Conclusion:** King Abdullah Medical City accomplished an international benchmark in door-to-balloon time for STEMI patients visiting the hospital for percutaneous coronary intervention during the hajj season.

**Keywords:** Door to balloon, Strategies, Primary Percutaneous Coronary Intervention.

## 1. Introduction:

The measurement of DTBT has emerged as a crucial metric in PCI in recent years and has been included in national guidelines as a fundamental performance indicator. Nevertheless, advancements in DTB duration have not been accompanied by proportional declines in mortality rates [1]. According to the guidelines, the objective DTBT is 90 minutes or less. First medical contact to device time of 120 minutes is recommended by both European and American ST Elevation Myocardial Infarction (STEMI) standards for the transfer STEMI population [2,3]. During the hajj season, many pilgrims are exposed to acute coronary syndrome and transfer to king Abdullah medical city (KAMC) for therapeutic interventions like percutaneous coronary intervention. Due to the high rate of admission, new strategies are implemented to provide high quality care to patients with AMI as a new pathway of the patient admission, Critical bed management group and Chest pain unit during hajj. So, the aim of this study is to determine the impact of King Abdullah medical city' strategies on door to balloon time in patients with STEMI.

## 2. Methods:

Prospective observational research using checklist for direct observation which included, part one covered patients' demographics such gender, age, marital status, education, diagnosis, and comorbidities and part 2: relevant times. This study was conducted in King Abdullah medical city. All patients undergoing PCI during hajj from 23/6/2023 to 7/7/2023 either direct admission or interhospital transfer were included. King Abdullah medical city hajj' strategies included new patient admission pathway implemented, WhatsApp group named Critical bed management group for administrative purposes aimed to check availability of beds to book beds for patients before arrival to the hospital and the chest pain unit, opens during Hajj season. All patients entered chest pain unit directly. This unit had three cubicles with 10 beds, including 3 beds for critically ill patients with mechanical ventilators, backup intubation, and 2 crash carts. Additionally, three cardiologists, two echo technicians, one respiratory therapist, one patient care technician, and two porters were assigned to the unit. The chest pain unit included a charge nurse and three nurse groups for the cubicles. One of the three

nurses in each group served as the team leader and was a senior critical care professional. All patients were required to undergo a fast-screening echo at the chest pain unit to rule out mechanical issues.

### 3. Results:

Table 1 shows that the median overall door to balloon time was 68 minutes for direct admission patients and 100 minutes for interhospital transferred patients with statistically significant,  $P= 0.001$ . The median time from diagnosis of AMI to Cath lab for direct admitted patients was 36.50 minutes and 60 minutes for transferred' patients with statistically significant,  $P= 0.001$ . For inter hospital transfer the median time from AMI diagnosis to second door (door of capable hospital) was 47 minutes and from arrival to capable hospital to balloon inflation was 28 minutes. The median time from D1 to D2 was 65 minutes and median time from D2 to balloon (patient arrival to KAMC to balloon) for interhospital transferred patients was 28 minutes which is within the recommended guidelines for patients transfer time.

Table 1: Parameters of door-to-balloon studied patients.

Parameters	Direct admission N (16)		Interhospital transfer N (51)		Z	P
	Median	IQR	Median	IQR		
1. Door-to-ECG time (m)	10.0	4.0	10.0	0.00	2.36	0.01*
2. ECG to AMI diagnosis time (m)	4.5	7.0	6.0	15.0	1.36	0.17
3. AMI diagnosis time to D2			47	35.0		
4. D1 to D2			65.0	40.0		
5. D2 to balloon			28.0	13.0		
6. Diagnosis of AMI to Cath lab time (m)	36.50	45.50	60.0	30.0	3.42	0.001*
7. Cath lab to balloon time (m)	18.50	16.50	15.0	10.0	1.58	0.11
8. Door to balloon time(m)	68.0	33.0	100.0	39.0	3.44	0.001*

Z: Mann-Whitney Test \* significant at  $P < 0.05$

Figure 1 illustrates that the median of D2BT for direct admitted' patients was found to be less than the standard time of D2BT for PCI capable hospital (68 m to 90 m respectively). For interhospital transfer patients median D2BT was 100 m compared with the 120 m for the standard time.

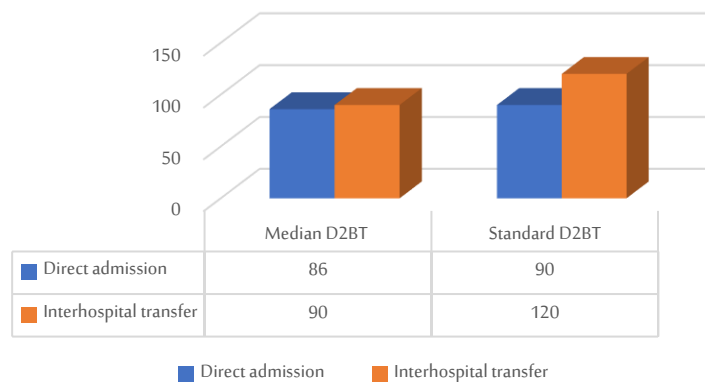


Figure 1: Comparison of DTBT with the standard time between direct admission and interhospital transfer.

Table 2 revealed that there is no statistically significant relationship between total DTBT and length of stay or total DTBT and in hospital mortality.

Table 2: Relationship between door to balloon time and length of stay and mortality.

Variables	Door to balloon time	
	r	p
▪ In hospital mortality	0.10	0.39
▪ Length of stay	0.09	0.42

#### 4. Discussion:

Our study found that the median DTBT for STEMI patients either direct admission or transfer was within the guidelines recommended time, this may be due to efficient coordination and communication between hospitals, sufficient resources, and staffing levels to handle interhospital transfers efficiently, dedicated transfer protocols implementation using aircraft and emergency medical services and availability of cardiac catheterization labs at KAMC. The findings of this study align with a previous investigation conducted in Saudi Arabia by Butt et al at a tertiary care institution in Riyadh which concluded that for individuals presenting with STEMI in the emergency department, PCI is the preferred therapeutic approach. Furthermore, the King Faisal Specialist Hospital and Research Centre in Riyadh has successfully attained and sustained an international benchmark of DTBT within 90 minutes through effective multidisciplinary collaboration [4].

Interhospital transfer patients were observed to have a shorter admission-to-balloon time than directly admitted patients. This discrepancy may be attributed to the initial assessment conducted at the referring hospital, which aids in discerning whether the patient was diagnosed with STEMI prior to their subsequent transfer to a PCI-capable medical center. Patients admitted directly to the chest pain unit benefit from available medical staff waiting for the patient's arrival, a prepared medical file, and Cath lab teams already at the hospital, waiting for the patients, instead of needing to come from their homes.

This result is in line with Hu et al and Kawecki et al, who reported that patients who were transported had a shorter Door-to-Balloon Time (DTBT) than those who arrived directly at hospitals with PCI capabilities [5,6].

The present study demonstrates that there is no statistically significant relationship between total door to balloon time and length of stay or total door to balloon time and in hospital mortality. The observed phenomenon may be attributed to the constrained sample size, which has resulted in restricted statistical power to identify major disparities and developments in medical practices during the hajj season.

This result is supported by Fan et al [7] who reveal that there are no statistically significant differences between in-hospital mortality rate and D2B time. In contrast Chew et al, Park et al and Foo et al found that delay in primary PCI could lead to increase in-hospital mortality [8,9]. Moreover, Li et al reported that Patients with ST-elevation myocardial infarction had a strong association between hospital costs and length of stay [10].

#### 5. Conclusion:

King Abdullah Medical City was able to accomplish a D2B time that set an international benchmark for STEMI patients who presented to the hospital for PCI during the hajj season, primarily through the implementation of strategic approaches to decrease DTBT. By implementing KAMC strategies, the processes of diagnosis, decision-making, and patient transfers will be executed in a synchronized and expeditious manner, resulting in improved patient care and less suffering. Further research into the effects of symptom onset to initial contact with a medical provider or balloon time on clinical outcome is also required.

## 6. Recommendation:

The imperative of KAMC's sustained commitment to the strategies that have facilitated the attainment of international benchmarks cannot be overstated. These strategies demand unwavering adherence throughout the entire year, transcending the confines of the hajj season. In pursuing this unwavering commitment, KAMC must institute a comprehensive quality improvement program. This program should be meticulously designed to vigilantly monitor key performance indicators specifically related to the DTB time for STEMI patients. Furthermore, KAMC should actively seek opportunities for knowledge exchange and collaboration with other esteemed healthcare institutions and hospitals. These collaborative endeavors should not be viewed as mere interactions but rather as platforms for the dissemination of best practices. Replicate this study with larger sample size and specific population to explore populational variations more comprehensively for generalization.

## References:

1. Menees DS, Peterson ED, Wang Y, Curtis JP, Messenger JC, Rumsfeld JS, Gurm HS. Door-to-balloon time and mortality among patients undergoing primary PCI. *New England Journal of Medicine*. 2013 Sep 5;369(10):901-9.
2. O'gara PT, Kushner FG, Ascheim DD, Casey DE, Chung MK, De Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Journal of the American college of cardiology*. 2013 Jan 29;61(4): e78-140.
3. Byrne RA, Rossello X, Coughlan JJ, Barbato E, Berry C, Chieffo A, Claeys MJ, Dan GA, Dweck MR, Galbraith M, Gilard M. 2023 ESC Guidelines for the management of acute coronary syndromes: Developed by the task force on the management of acute coronary syndromes of the European Society of Cardiology (ESC). *European Heart Journal*. 2023 Aug 25: ehad191.
4. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, Caforio AL, Crea F, Goudevens JA, Halvorsen S, Hindricks G. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *European heart journal*. 2018 Jan 7;39(2):119-77.
5. Butt TS, Bashtawi E, Bououn B, Wagley B, Albarrak B, Sergani HE, Mujtaba SI, Buraiki J. Door-to-balloon time in the treatment of ST segment elevation myocardial infarction in a tertiary care center in Saudi Arabia. *Annals of Saudi Medicine*. 2020 Jul;40(4):281-9.
6. Hu D, Hao Y, Liu J, Yang N, Yang Y, Sun Z, Zhao D, Liu J. Inter-hospital transfer in patients with acute myocardial infarction in China: findings from the improving care for cardiovascular disease in china-acute coronary syndrome project. *Frontiers in Cardiovascular Medicine*. 2022 Dec 8; 9:1064690.
7. Dhungel S, Malla R, Adhikari C, Maskey A, Rajbhandari R, Sharma R, Nepal H, Rauniyar B, Yadav D, Limbu D, Gautam M. Door-to-balloon time, and the determining factors in a tertiary cardiac center in Nepal. *Indian Heart Journal*. 2018 Dec 1;70: S309-12.
8. Nathan AS, Raman S, Yang N, Painter I, Khatana SA, Dayoub EJ, Herrmann HC, Yeh RW, Groeneveld PW, Doll JA, McCabe JM. Association between 90-minute door-to-balloon time, selective exclusion of myocardial infarction cases, and access site choice: insights from the cardiac care outcomes assessment program (COAP) in Washington State. *Circulation: Cardiovascular Interventions*. 2020 Sep;13(9): e009179.
9. Fan CM, Lai CL, Li AH, Chung KP, Yang MC. Shorter door-to-balloon time in ST-elevation myocardial infarction saves insurance payments: a single hospital experience in Taiwan. *Acta Cardiologica Sinica*. 2015 Mar;31(2):127.
10. Foo CY, Bonsu KO, Nallamothu BK, Reid CM, Dhipayom T, Reidpath DD, Chaiyakunapruk N. Coronary intervention door-to-balloon time and outcomes in ST-elevation myocardial infarction: a meta-analysis. *Heart*. 2018 Aug 1;104(16):1362-9.



## Effectiveness of Wearing Face Mask for Prevention of Respiratory Tract Infection During Hajj: A Systematic Review and Meta-Analysis

Raghad Alhajaji<sup>1&2</sup>, Khalid Al Sulaiman,<sup>4,5&16\*</sup> Omar A. Abdelwahab<sup>9&10</sup>, Manal Alfahmi<sup>6,7&8</sup>, Jameel T. Abualenain<sup>12&13</sup>, Sari I. Asiri<sup>1&11</sup>, Ohoud Aljuhani<sup>14&16</sup>, Aisha Alharbi<sup>15</sup>, Hadeel Alkofide<sup>17</sup>, Malaz Ahmed, Ahmed Y. Saedi<sup>1&11</sup>, Ahmad Alturkistani<sup>1</sup>, Ahmed Al-Jedai<sup>18</sup>

1-Public Health Administration, Makkah Health Affairs, Ministry of Health, 2-Alhajj Primary Health Care, Makkah Health Cluster, 3-Pharmaceutical Care Department, King Abdulaziz Medical City, 4-College of Pharmacy, King Saud bin Abdulaziz University for Health Sciences, 5-King Abdullah International Medical Research Center, 6- Clinical research Administration at the Executive Administration of Research and Innovation, King Abdullah Medical City (KAMC), 7-Executive Administration of Research and Innovation, King Abdullah Medical City (KAMC), 8-King Abdullah Medical City (KAMC) Medical Ethics committee, 9-Faculty of Medicine, Al-Azhar University, Cairo, Egypt, 10-Medical Research Group of Egypt, Cairo, Egypt, 11-The General Directorate of Hajj and Umrah, Ministry of Health, 12-General Directorate of Emergencies, Disasters, & Medical Transportation, Deputyship of Curative Services, Ministry of Health, 13-Department of Emergency Medicine, Faculty of Medicine, King Abdulaziz University, 14-Department of Pharmacy Practice, Faculty of Pharmacy, King Abdulaziz University, 15-Pharmaceutical Care Department, King Abdulaziz Medical City, 16- Saudi Critical Care Pharmacy Research (SCAPE) Platform, 17-Department of Clinical Pharmacy, College of Pharmacy, King Saud University, 18-Therapeutic Affairs Deputyship, Ministry of Health, Riyadh, Saudi Arabia; Colleges of Medicine and Pharmacy, Al-Faisal University, Riyadh, Saudi Arabia.

\*Corresponding author: E-mail (Raghad.alhajaji@gmail.com)

### فعالية ارتداء الكمامة للوقاية من العدوى في الجهاز التنفسي خلال فترة الحج: استعراض منهجي وتحليل شامل

رغد الحجاجي<sup>2&1</sup>, خالد السليمان<sup>16,5,4\*</sup>, عمر عبد الوهاب<sup>10,9</sup>, منال الفهيم<sup>8,7,6</sup>, جميل أبو العينين<sup>13,12</sup>, سري عسيري, عهود الجبهي<sup>11,1</sup>, عائشة الحربي<sup>15</sup>, هديل القفدي<sup>17</sup>, ملاذ أحمد, أحمد السعيد<sup>11,1</sup>, أحمد التركستاني<sup>1</sup>, أحمد الجديدي<sup>18</sup>

#### الملخص

المقدمة: الحج هو أكبر تجمع جماهيري على مستوى العالم يقام سنوياً في مكة المكرمة، المملكة العربية السعودية. وتعتبر الأمراض التنفسية الأكثر شيوعاً بين الأمراض المعدية بسبب إمكانية انتشارها السريع في البيئات المزدحمة. ويوجد نقص في البيانات المتعلقة بفعالية ارتداء الأقنعة الواقية في منع العدوى في المسارات التنفسية، خاصة أثناء أداء فريضة الحج. الطرق: قمنا بالبحث بشكل منهجي في قواعد البيانات PubMed و Scopus و Web of Science ومركز كوكرين للتسجيل المركزي للتجارب المراقبة حتى 3 يوليو 2023 عن الدراسات التي تقارن معدل حدوث أو انتشار العدوى في الجهاز التنفسي بين الذين ارتدوا أي نوع من الأقنعة الواقية خلال أداء فريضة الحج وبين الذين لم يرتدوا الأقنعة. كما تم فحص مصادر أخرى، مثل Google Scholar في الأوراق المدرجة أيضاً. تم حساب نسبة الخطر (RR) وفترات الثقة بنسبة 95% (CI) باستخدام نموذج إما ثابت أو عشوائي تبعاً للنتائج. شمل التحليل الشامل عشر دراسات تشمل 16713 مشاركاً. أظهرت نتائج نسبة الخطر الإجمالية تفضيل ارتداء الأقنعة على عدم ارتدائها فيما يتعلق بحدوث العدوى في الجهاز التنفسي؛ ومع ذلك، لم يكن الفارق ذا دلالة إحصائية (RR = 0.78; 95% CI = [0.55, 1.10], P = 0.16). تم العثور على حدوث عدوى بالغة الندرة بشكل ملحوظ في أولئك الذين يرتدون الأقنعة معظم الوقت مقارنة بارتدائها بشكل متقطع (RR = 0.59; 95% CI = [0.38, 0.94], P = 0.02). في تحليل الفرع، لم يكن هناك فارق بين ارتداء الأقنعة وعدم ارتدائها بين التصميمات الدراسية المختلفة (تصميم السيرة الذاتية أو دراسة الحالة) والمجموعات المختلفة (الحجاج أو العاملين في مجال الرعاية الصحية) وسنوات الحج المختلفة، باستثناء الفترة من 2002 إلى 2008 حيث كان هناك فارق كبير يفضل ارتداء الأقنعة الواقية.

الختام: أظهرت هذه التحليلات الشاملة أن ارتداء الأقنعة معظم الوقت كان مرتبطاً بخطر أقل بشكل ملحوظ للإصابة بالعدوى في الجهاز التنفسي مقارنة بارتدائها بشكل متقطع. بالإضافة إلى ذلك، كان ارتداء الأقنعة مرتبطاً بمعدل أقل للإصابة بالعدوى في الجهاز التنفسي مقارنة بعدم ارتدائها؛ ومع ذلك، لم يصل الفارق إلى الدلالة الإحصائية.

## Abstract

**Background:** Hajj is the largest annual mass gathering worldwide, taking place annually in Makkah, Saudi Arabia". Respiratory infections are the most common infectious disease due to their potential for rapid spread in crowded settings. However, there is a lack of data regarding the effectiveness of face masks in preventing respiratory tract infections (RTIs), specifically during Hajj.

**Methods:** We systematically searched PubMed, Scopus, Web of Science, and Cochrane Central Register of Controlled Trials until 3 July 2023 for studies comparing the incidence or prevalence of RTI in those who used any face mask during Hajj compared to no mask. Other sources, such as Google Scholar in the included papers, were also screened. Risk ratio (RR) and 95% confidence intervals (CIs) were calculated using either a fixed or random-effect model, depending on the heterogeneity.

**Results:** A comprehensive analysis encompassed ten studies involving 16713 participants. The overall RR favored wearing masks over not wearing masks regarding the incidence of RTI; however, the difference was not statistically significant (RR= 0.78; 95% CI= [0.55, 1.10, P= 0.16). A significantly lower incidence of RTI was found in those wearing masks most of the time versus intermittently (RR= 0.59; 95% CI= [0.38, 0.94, P= 0.02). In subgroup analysis, there was no difference between wearing masks and not wearing masks across different study designs (cohort or case-control), different groups (pilgrims or healthcare workers), and different years of Hajj, except from 2002 to 2008, there was a significant difference favoring wearing facemasks. Conclusion: This meta-analysis found that wearing masks most of the time was associated with a significantly lower risk of RTI than wearing the mask intermittently. In addition, wearing masks was associated with lower RTI than no masks; however, the difference did not reach statistical significance.

## 1. Introduction

The annual Islamic religion of Hajj in Saudi Arabia is among the largest gatherings of people in the world, attracting millions of pilgrims from various countries and continents (1–3). However, these gatherings pose significant public health challenges due to the large number of people in confined spaces, leading to an increased risk of infectious disease transmission, including respiratory infections (2–4). More than 60% of the pilgrims participating in the mass gathering of the Hajj pilgrimage are found to acquire respiratory pathogens through their nasal acquisition (5). A considerable majority of pilgrims experience the onset of respiratory tract infections (RTIs) shortly after they arrive in Makkah (6). Factors contributing to the increased incidence of RTIs during Hajj include crowded conditions, the use of shared accommodations, limited access to handwashing facilities, poor respiratory hygiene practices, climate conditions during the Hajj season, and intercontinental travel by pilgrims, which introduces a variety of respiratory pathogens from different regions (7-10). Outbreaks of respiratory diseases, including influenza, coronaviruses, and other respiratory pathogens, have been reported in the past (11). The recent COVID-19 pandemic has further highlighted the need for stringent preventive measures during mass gatherings to safeguard public health (11). Among the various preventive measures for respiratory diseases, face masks have emerged as a prominent intervention to reduce the transmission of respiratory pathogens. Face masks act as a physical barrier that can block respiratory droplets containing infectious agents from being released into the air, reducing the risk of transmitting to others (12–14).

According to data from randomized trials, using face masks might slightly reduce the likelihood of acquiring primary infection with influenza-like illness (ILI) and COVID-19. Furthermore, studies report that wearing face masks may reduce primary respiratory infection risk by 6–15%. However, it is crucial to note that many of these trials report substantially low adherence to mask-wearing, and some control groups also wore face masks without detection (13,15). Despite their widespread use in various settings, the effectiveness of face masks during large-scale gatherings like Hajj and Umrah remains a subject of scientific inquiry (16–18). Saudi authorities have made incredible, meaningful efforts to implement high standards of preventive measures during Hajj To maintain health security during the Hajj season and to reduce the transmission of respiratory infections. These measures include the latest updated policies of health screenings at entry points, public health awareness campaigns, vaccination, prophylactic drugs, distribution of face masks, and emphasizing respiratory etiquette and hand hygiene (16,19,22). Despite these efforts, The Ministry of Health's dedicated public health authorities prioritize the well-being of pilgrims as their paramount concern. They consistently monitor and comprehensively study the incidence of RTIs during the Hajj pilgrimage, with an unwavering commitment to developing precise, impactful interventions.

This unwavering dedication mitigates the impact of RTIs, always ensuring the safeguarding of pilgrims' health (16,20). A previous systematic review meta-analysis by Liang et al., evaluating the efficacy of face masks in preventing the transmission of respiratory viruses, found a significant protective effect with face masks (21). Furthermore, the author reported a reduced risk of respiratory virus infection by 80% if masks were used by healthcare workers and 47% if used by non-healthcare workers. On the contrary, the findings of Xiao et al., a systematic review and meta-analysis of 10 RCTs, indicated that masks did not significantly impact the transmission of influenza (22). Furthermore, Smith et al., meta-analysis reported no significant difference in the risk of laboratory-confirmed respiratory infection between N95 and surgical masks (23). Up to date, the available evidence regarding the effectiveness of masks in preventing respiratory viral transmission is inconclusive and conflicting, especially during large-scale gatherings like Hajj and Umrah. Therefore, this systematic review and meta-analysis aim to evaluate the effectiveness of wearing face masks among individuals participating in the Hajj in reducing the incidence of respiratory infections.

## 2. Methodology (Materials and methods)

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline was followed during the design of this study (24). Furthermore, the Cochrane Handbook for Systematic Reviews and Meta-Analysis of Interventions guidelines was followed throughout the process (25). To ensure transparency and accountability, the study protocol was registered on PROSPERO under the reference number CRD42023449026.

### 2.1 Search Strategy

We conducted an extensive search across four electronic databases (PubMed, Scopus, Web of Science, and Cochrane Central Register of Controlled Trials) from their inception until 3 July 2023. Our search strategy involved using the following query: "(hadj OR hajj OR mass gathering OR pilgrimage OR pillar of Islam OR pilgrims) AND (mask OR Facemask OR face mask OR Respirator OR N95 FFR OR respiratory mask OR respiratory protection)". Furthermore, we manually examined the references cited in the included papers to identify additional relevant studies. Additionally, we manually searched gray literature sources, such as Google Scholar, to identify any other pertinent articles that the electronic database search missed. This comprehensive approach aimed to gather a wide range of evidence for our meta-analysis and systematic review.

## 2.2 Study Selection

Studies were considered for this review if they satisfied the following criteria: Population: Muslim Hajj pilgrims from any nationality. Exposure: Any type of face mask, whether the participants adhered entirely to it or partially. Comparator: Not using a face mask during Hajj. Outcome: The incidence or prevalence of RTI as defined by the included studies. We aim to include randomized controlled trials, cohort, and case-control studies, although we plan to analyze interventional studies separately from observational studies. We excluded studies with unreliable data for extraction and analysis, cluster randomized controlled trials, cross-sectional studies, studies reported solely as abstracts or theses, studies without full-text availability, case reports, case series, review articles, and studies not published in English. By applying these criteria, we sought to ensure that the studies included in our review were relevant and of sufficient quality to contribute to our analysis.

## 2.3 Study Screening

Duplicate removal was performed using Endnote (Clarivate Analytics, PA, USA). The screening process consisted of two stages. In the first stage, two authors independently screened the titles and abstracts of all identified papers to assess their eligibility for inclusion in the review. In the second stage, the full texts of the articles that passed the abstract screening were assessed by two independent reviewers to determine their final eligibility for inclusion in the meta-analysis. In cases where disagreements arose, a third reviewer facilitated discussion and resolution. This rigorous screening process ensured the selection of appropriate studies for the review.

## 2.4 Data extraction and quality assessment

Two independent investigators extracted data to a uniform data extraction sheet, and any disagreements were resolved by consulting with a third investigator. The extracted data included information related to the included studies' characteristics, the population of included studies, and the outcome measures of interest. We used the Newcastle Ottawa scale (NOS) to assess the risk of bias for observational cohort and case-control studies (26). This tool estimates the risk of bias in observational studies based on reporting three essential domains: selection of the study subjects, comparability of groups regarding demographic characteristics and essential potential confounders and ascertaining the pre-specified outcome. Observational studies were categorized as being of "good quality" or "low quality" based on the total score of NOS (maximum of 9). Studies with a total score of 7 or more are considered "good quality," studies between 4 and 6 are considered "fair quality," while studies with a score below four are considered "low quality." The quality of the outcome findings was evaluated by one reviewer (O.A.) using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) guidelines (27, 28). We considered publication bias, risk of bias, imprecision, indirectness, and inconsistency. For every result, our findings regarding the quality of the evidence were explained, rationalized, and included.

## 2.5 Study Outcomes

The study's primary outcome was to examine the occurrence of respiratory tract infections (RTIs) among individuals who wore masks consistently, as opposed to those who did not wear masks or wore them inconsistently. Secondary outcomes were a comprehensive subgroup analysis, including the populations being studied (healthcare providers versus pilgrims), the specific year of the Hajj pilgrimage, and the participants' influenza vaccination status.



## 2.6 Data Synthesis

Review Manager software (version 5.4) was used to analyze the study data. Since all the study outcomes are dichotomous data, we performed meta-analyses of associations by using raw numbers or adjusted analysis depending on the availability of these data. When the number of events was available, the data was pooled as risk ratio (RR) (with the corresponding 95% confidence intervals (CI)) between the two groups. We used the fixed effect model if no heterogeneity was observed and the DerSimonian Liard random-effect model if there was a significant heterogeneity. The Chi-square test (Cochrane Q test) evaluated statistical heterogeneity among studies. A chi-square P-value of less than 0.1 or an I-square of  $\geq 50\%$  indicated high heterogeneity. We performed the primary analysis by comparing wearing face masks to not wearing face masks; however, we performed a separate analysis comparing intermittent versus sometimes facemask uses and intermittent versus not using facemasks whenever these data were available in the included studies. To test the robustness of the evidence, we conducted a certainty assessment through sensitivity analysis (also called leave-one-out meta-analysis). For every outcome in the meta-analysis, we ran sensitivity analysis in multiple scenarios, excluding one study in each scenario to ensure the overall effect size was not dependent on any single study. In addition, we performed subgroup analysis to investigate whether the effect of using facemasks differs by specific subgroups. These subgroup analyses were performed by type of study design (cohort versus case-control studies), population included (healthcare providers versus pilgrims), year of Hajj, and influenza vaccination status whenever such data were available.

## 3. Results and Discussion

### 3.1 Literature search results

The initial literature search retrieved 589 records. After screening the titles and abstracts, forty-seven articles met the eligibility criteria for full-text screening. From these, nine studies were deemed suitable for inclusion in the analysis. Additionally, one article was manually identified through a search on Google Scholar. The references of the included studies were also manually searched, but no additional articles met the inclusion criteria. In total, ten studies were included in the final meta-analysis. Figure 8 illustrates the study selection process using a PRISMA flow diagram (24).

### 3.2 Characteristics of the included studies

Ten studies were included in the meta-analysis, with a total of 16713 pilgrims and participants. Eight were prospective cohorts, and two case-control studies (1,4, 29-36) The summary of the included studies and the baseline characteristics of the population of each study are provided in Table 1 and Table 2, respectively. Overall, the quality of the included studies was good, as shown in Tables S2 and S3.

### 3.3 Incidence of RTI

#### 3.1.1 Wearing mask vs not wearing mask

Eight studies were included in this outcome, with a total of 3291 participants. The overall RR between the two groups favored wearing masks regarding the incidence of RTI; however, it was not statistically significant (RR= 0.78; 95% CI= [0.55, 1.10], P= 0.16) (Very low-quality evidence, Table S2 and S3). The pooled studies were not homogenous ( $P < 0.001$ ;  $I^2 = 96\%$ ), as shown in **Figure 1**. We performed a sensitivity analysis, removing one study from the analysis in each scenario; however, none of the scenarios changed the results significantly.

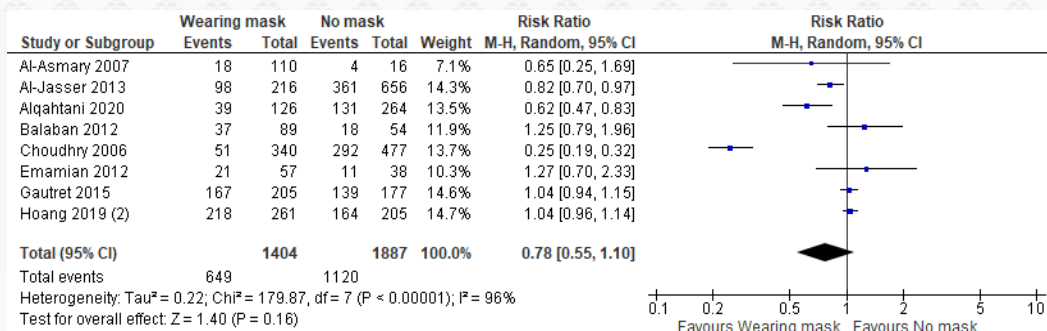


Figure 1 Forest plot showing the RTI risk ratio using random-effects models in patients wearing masks versus no masks

### 3.3.2 Wearing mask most of time versus intermittently wearing

Three studies reported the outcome of RTI in subjects wearing masks most of the time versus intermittently with a total of 1633 participants. The overall RR showed that wearing the mask most of the time was associated with a lower incidence of RTI compared to intermittently wearing the mask (RR= 0.59; 95% CI= [0.38, 0.94], P= 0.02) (Low-quality evidence, Table S2 and S3). The pooled studies were not homogenous (P= 0.001; I<sup>2</sup>=85%), as shown in **Figure 2**. Using the leave-one-out analysis, the heterogeneity was decreased by excluding Al-Jasser et al. 2013 study (2) (P= 0.99; I<sup>2</sup>=0%), but the results still favored the wearing mask most of the time than intermittently, as shown in Figure SX1 (RR= 0.48; 95% CI= [0.36, 0.62], P< 0.001) (Moderate-quality evidence, Table S2 and S3).

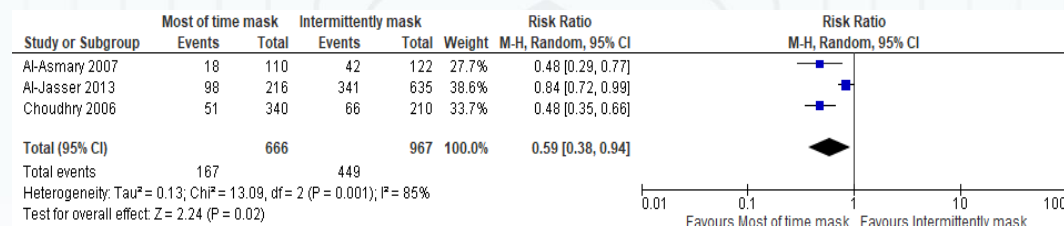


Figure 2 Forest plot showing the RTI risk ratio using random-effects models in patients wearing masks most of the time versus intermittently wearing masks

### 3.3.3 Wearing mask intermittently versus not wearing mask

Three studies reported the outcome of RTI in subjects wearing masks intermittently versus not wearing masks with a total of 2116 participants. As shown in **Figure 3**, the overall RR between the wearing mask intermittently and not wearing mask groups did not favor either of the two groups regarding the incidence of RTI (RR= 0.81; 95% CI= [0.47, 1.42], P= 0.47) with significant heterogeneity (P<0.001, I<sup>2</sup>=94%) (very low-quality evidence, Table S2 and S3).

The heterogeneity was decreased by excluding Choudhry et al. 2006 study (P= 0.45; I<sup>2</sup>=0%), but the results still not favoring any of the two groups (RR= 0.98; 95% CI= [0.89, 1.08], P= 0.69; I<sup>2</sup>=0%) (Figure SX2) (Low-quality evidence, Table S2 and S3).

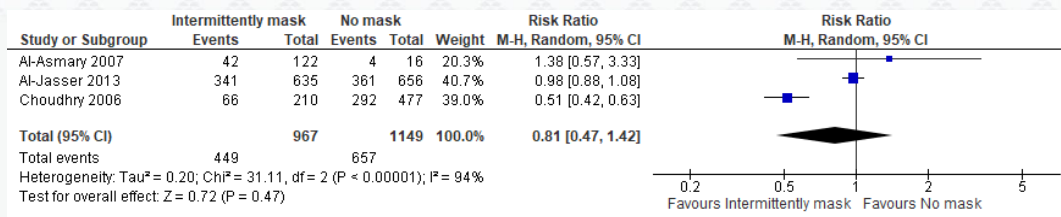


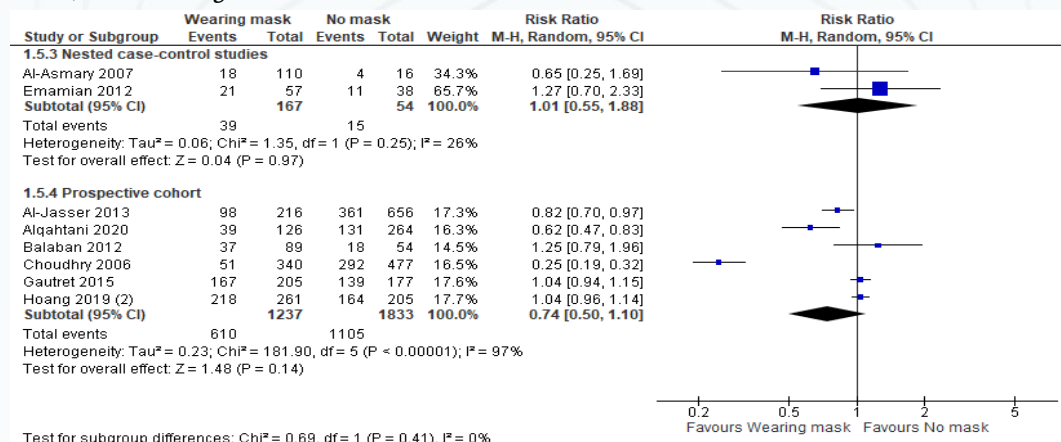
Figure 3 Forest plot showing the RTI risk ratio using random-effects models in patients wearing masks intermittently versus not wearing masks

Sub-group analysis for RTI (Wearing mask versus No mask):

### 2.6.1 Based on the study design

The test for subgroup differences was not significant across the groups. There was no difference between wearing face masks and not wearing facemasks in the case-control studies (RR= 1.01; 95% CI= [0.55, 1.88, P= 0.97, I<sup>2</sup>=26%).

On the other hand, in the prospective cohort studies, the overall RR of RTI between the two groups favored wearing masks over no mask; however, it failed to reach the statistically significant (RR= 0.74; 95% CI= [0.50, 1.10, P= 0.14, I<sup>2</sup>=97%) as shown in **Figure 4**.



Test for subgroup differences: Chi<sup>2</sup> = 0.69, df = 1 (P = 0.41), I<sup>2</sup> = 0%

Figure 4 Forest plot showing the RTI risk ratio using random-effects models in subgroup analysis based on study design for patients wearing masks versus not wearing masks

### 2.6.2 Based on the population (Healthcare providers' vs pilgrims)

Based on the population as subgroup analysis, the overall RR of RTI between the two groups favored wearing masks over no mask in pilgrims but did not reach statistical significance (RR= 0.79; 95% CI= [0.55, 1.14], P= 0.20; I<sup>2</sup>=97%). As shown in **Figure 5**, the test for subgroup differences was not significant between the two groups.

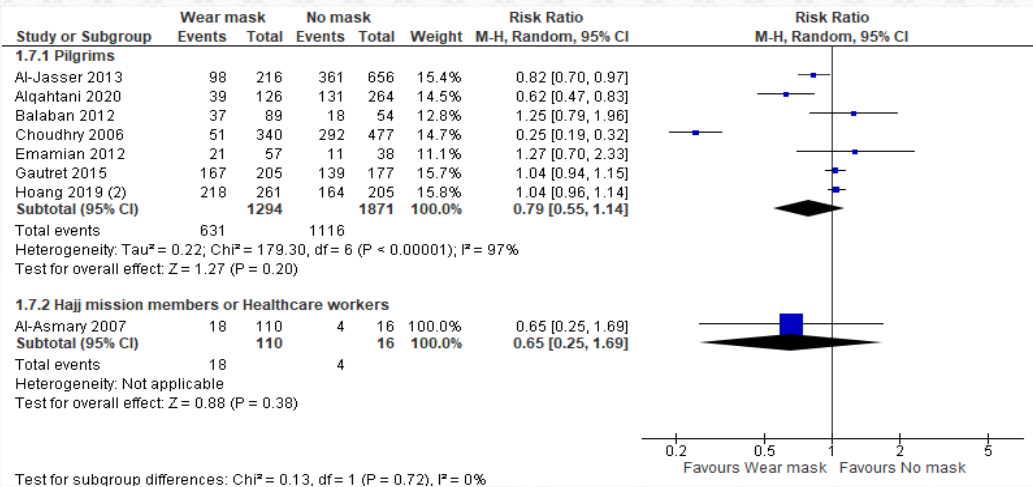


Figure 5 Forest plot showing the RTI risk ratio using random-effects models in subgroup analysis based on populations for patients wearing masks versus not wearing masks

### 2.6.3 Based on the year of the hajj

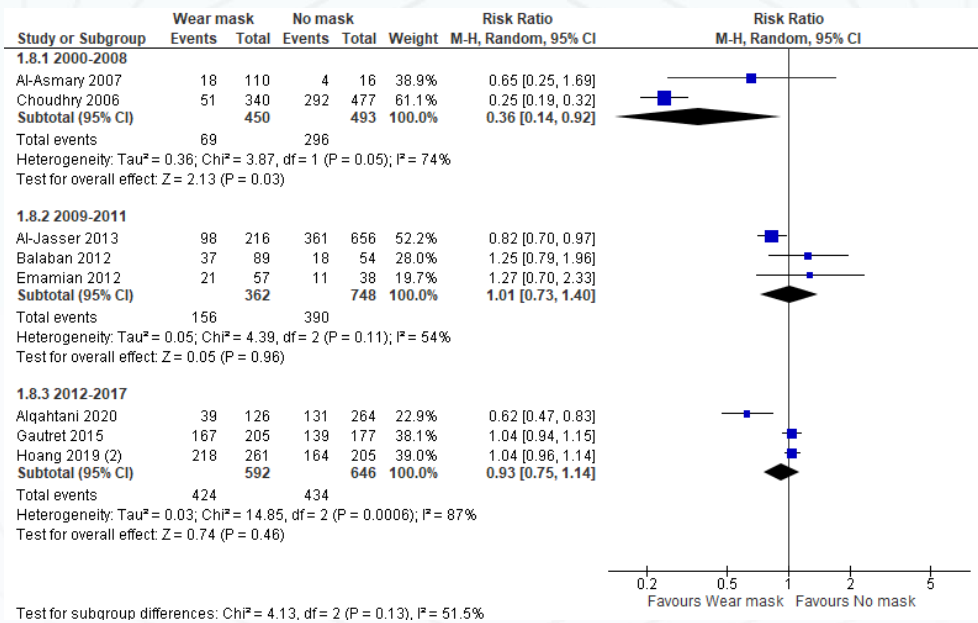


Figure 6 Forest plot showing the RTI risk ratio using random-effects models in subgroup analysis based on the Hajj year's. As shown in Figure 6, the test for subgroup differences was non-significant across the groups. From 2002 to 2008, there was a statistically significant difference favoring wearing face masks over not wearing facemasks (RR= 0.36; 95% CI= [0.14, 0.92]; P=0.03, I<sup>2</sup>=74%); however, only two studies were included in this period. In contrast, there was no significant difference between the groups in 2009 to 2011 and 2012 to 2017 periods (RR= 1.01; 95% CI= [0.73, 1.40]; P= 0.96, I<sup>2</sup>=54% and RR= 0.93; 95% CI= [0.75, 1.14]; P= 0.46, I<sup>2</sup>=87 %, respectively).

## 2.6.4 Based on the year of the influenza vaccination status

The test for subgroup differences based on influenza vaccination status showed a statistically significant difference. The effect of wearing facemasks on the RR was not statistically significantly lower RTI when 50% or above of the population were vaccinated against influenza (RR= 0.80; 95% CI= [0.60, 1.06], P= 0.19, I<sup>2</sup>=62%), or even when < 50% of the population were vaccinated (RR= 1.04; 95% CI= [0.98, 1.11];, P= 0.21, I<sup>2</sup>=0%), as shown in **Figure 7**.

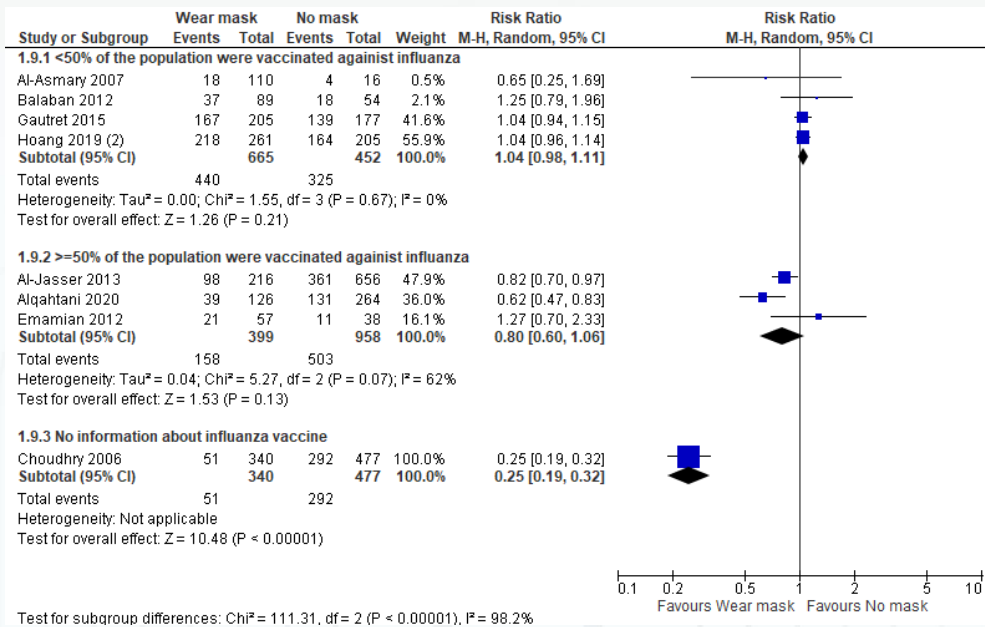


Figure 7 Forest plot showing the RTI risk ratio using random-effects models in subgroup analysis based on influenza vaccination status

## 4. Conclusions

This meta-analysis and systematic review provide nuanced insights into the relationship between face mask usage and the incidence of RTIs among Muslim Hajj pilgrims. This study found that wearing masks most of the time was associated with a significantly lower risk of RTI than wearing the mask intermittently. While consistent mask usage appears to be associated with reduced RTI risk, the effectiveness of masks in preventing RTIs during the pilgrimage requires further consideration in light of various scenarios and subgroups. These findings underscore the need for tailored public health strategies to optimize mask usage and minimize RTI transmission during mass gatherings like the Hajj pilgrimage.

## 5. Recommendations

Our findings emphasize the significance of supporting regular and adequate face mask use among Hajj pilgrims to potentially reduce the risk of RTIs. There were several advantages to our study. In the first place, this is the most recent systematic review and meta-analysis that examines the effectiveness of face mask use in the context of the Hajj. Second, we conducted subgroups based on various circumstances to account for all variables, including the study design, the demographic (healthcare providers vs. pilgrims), the hajj year, and the level of immunization. Third, we made an utterly novel comparison in a meta-analysis (between wearing a mask sporadically vs. never wearing one vs. wearing one most of the time).

It is crucial to note any limitations that can influence how the results could be interpreted. The heterogeneity in outcomes between several circumstances cautions against a one-size-fits-all strategy. The heterogeneity among the studies under consideration may be due to variations in study design, population demographics, and environmental factors. Considerable variation persists despite efforts to reduce heterogeneity through sensitivity and subgroup analysis. Additionally, the investigation's focus on the particular community of Muslim Hajj pilgrims' places constraints on the generalizability of the findings. The dynamics of the Hajj, especially its dense crowds and limited geographical area, may not be easily generalized to other environments or communities that experience massive gatherings. Furthermore, the reliance on published studies introduces the potential for publication bias, wherein studies with statistically significant results are more likely to be published. Although efforts were made to assess and account for publication bias through a statistical test, the influence of unpublished studies or studies in languages other than English cannot be completely ruled out. Lastly, the limited number of randomized controlled trials and the inclusion of various study designs may introduce variability in the quality and rigor of the evidence. Thus, future research should consider these limitations and further assess other preventive measures during Hajj and additional factors that might influence their effectiveness.

## References

1. Al Jasser FS, Kabbash IA, Al Mazroa MA, Memish ZA. Patterns of diseases and preventive measures among domestic hajjis from Central, Saudi Arabia [complete republication]. *Eastern Mediterranean Health Journal*. 2013;19(Supp. 2).
2. Alqahtani AS, Althimiri NA, BinDhim NF. Saudi Hajj pilgrims' preparation and uptake of health preventive measures during Hajj 2017. *J Infect Public Health*. 2019;12(6).
3. Saad A. Health issues during Hajj. *Egypt J Intern Med*. 2017;29(2).
4. Gautret P, Benkouiten S, Griffiths K, Sridhar S. The inevitable Hajj cough: Surveillance data in French pilgrims, 2012–2014. *Travel Med Infect Dis*. 2015;13(6).
5. Memish ZA, Assiri A, Turkestani A, Yezli S, al Masri M, Charrel R, et al. Mass gathering and globalization of respiratory pathogens during the 2013 Hajj. *Clinical Microbiology and Infection*. 2015;21(6).
6. Hoang VT, Dao TL, Ly TDA, Belhouchat K, Chaht KL, Gaudart J, et al. The dynamics and interactions of respiratory pathogen carriage among French pilgrims during the 2018 Hajj. *Emerg Microbes Infect*. 2019;8(1).
7. Gautret P, Benkouiten S, Al-Tawfiq JA, Memish ZA. Hajj-associated viral respiratory infections: A systematic review. Vol. 14, *Travel Medicine and Infectious Disease*. 2016.
8. Alzeer AH. Respiratory tract infection during Hajj. *Ann Thorac Med [Internet]*. 2009 Jul 1 [cited 2023 Aug 11];4(2):50. Available from: [/pmc/articles/PMC2700482/](#)
9. Salmon-Rousseau A, Piednoir E, Cattoir V, de La Blanchardière A. Hajj-associated infections. *Med Mal Infect [Internet]*. 2016 Oct 1 [cited 2023 Aug 11];46(7):346. Available from: [/pmc/articles/PMC7131558/](#)
10. Koul PA, Mir H, Saha S, Chadha MS, Potdar V, Widdowson MA, et al. Respiratory viruses in returning Hajj & Umrah pilgrims with acute respiratory illness in 2014-2015. *Indian J Med Res [Internet]*. 2018 Sep 1 [cited 2023 Aug 11];148(3):329. Available from: [/pmc/articles/PMC6251276/](#)
11. Noor R, Maniha SM. A brief outline of respiratory viral disease outbreaks: 1889–till date on the public health perspectives. Vol. 31, *VirusDisease*. 2020.
12. European Centre for Disease Prevention and Control. Using face masks in the community: first update (Effectiveness in reducing transmission of COVID-19 Key messages). ECDC. 2021;February(Stockholm).
13. Brainard J, Jones NR, Lake IR, Hooper L, Hunter PR. Community use of face masks and similar barriers to prevent respiratory illness such as COVID-19: A rapid scoping review. Vol. 25, *Eurosurveillance*. 2020.

14. of Health D. The Use of Facemasks and Respirators during an Influenza Pandemic Scientific Evidence Base Review. 2014 [cited 2023 Aug 8]; Available from: [www.nationalarchives.gov.uk/doc/open-government-licence/](http://www.nationalarchives.gov.uk/doc/open-government-licence/)
15. de Camargo MC, Martinez-Silveira MS, Lima AA, Bastos BP, Dos Santos DL, Mota SE de C, et al. Effectiveness of the use of non-woven face mask to prevent coronavirus infections in the general population: A rapid systematic review. *Ciencia e Saude Coletiva*. 2020;25(9).
16. Alfelali M, Haworth EA, Barasheed O, Badahdah AM, Bokhary H, Tashani M, et al. Facemask against viral respiratory infections among Hajj pilgrims: A challenging clusterrandomized trial. *PLoS One*. 2020;15(10 October).
17. Barasheed O, Almasri N, Badahdah AM, Heron L, Taylor J, McPhee K, et al. Pilot Randomised Controlled Trial to Test Effectiveness of Facemasks in Preventing Influenza-like Illness Transmission among Australian Hajj Pilgrims in 2011. *Infect Disord Drug Targets*. 2014;14(2).
18. Azman MA, Yusof SAM, Abdullah I, Mohamad I, Mohammed JS. Factors influencing face mask selection and design specifications: Results from pilot study amongst Malaysian Umrah pilgrims. *J Teknol*. 2017;79(3).
19. General Guide for Health of Hajj and Umrah Pilgrims.
20. Wang M, Barasheed O, Rashid H, Booy R, El Bashir H, Haworth E, et al. A cluster-randomised controlled trial to test the efficacy of facemasks in preventing respiratory viral infection among Hajj pilgrims. *J Epidemiol Glob Health*. 2015;5(2).
21. Liang, Mingming, Liang Gao, Ce Cheng, Qin Zhou, John Patrick Uy, Kurt Heiner, and Chenyu Sun. "Efficacy of Face Mask in Preventing Respiratory Virus Transmission: A Systematic Review and Meta-Analysis." *Travel Medicine and Infectious Disease* 36 (2020): 101751. <https://doi.org/10.1016/j.tmaid.2020.101751>.
22. Xiao, Jingyi, Eunice Y. Shiu, Huizhi Gao, Jessica Y. Wong, Min W. Fong, Sukhyun Ryu, and Benjamin J. Cowling. "Nonpharmaceutical Measures for Pandemic Influenza in Nonhealthcare Settings—Personal Protective and Environmental Measures." *Emerging Infectious Diseases* 26, no. 5 (2020): 967–75. <https://doi.org/10.3201/eid2605.190994>.
23. Smith, Jeffrey D., Colin C. MacDougall, Jennie Johnstone, Ray A. Copes, Brian Schwartz, and Gary E. Garber. "Effectiveness of N95 Respirators versus Surgical Masks in Protecting Health Care Workers from Acute Respiratory Infection: A Systematic Review and Meta-Analysis." *Canadian Medical Association Journal* 188, no. 8 (2016): 567–74. <https://doi.org/10.1503/cmaj.150835>.
24. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. Vol. 372, *The BMJ*. 2021.
25. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al. Cochrane handbook for systematic reviews of interventions version 6.2 [updated February 2021]. *Cochrane Handbook for Systematic Reviews of Interventions*. 2021.
26. Wells G, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle–Ottawa Scale (NOQAS) for Assessing the Quality of Non-Randomized Studies in Meta-Analysis. *The Ottawa Hospital*. 2004;
27. Guyatt GH, Oxman AD, Vist GE et al (2008) Rating Quality of Evidence and Strength of Recommendations: GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ Br Med J* 336:924. <https://doi.org/10.1136/BMJ.39489.470347.AD>
28. Handbook G, Schünemann H, Brozek J, Guyatt G, Oxman A (2013) Handbook for grading the quality of evidence and the strength of recommendations using the GRADE approach (updated October 2013). GRADE Working Group 2013
29. Al-Asmary S, Al-Shehri AS, Abou-Zeid A, Abdel-Fattah M, Hifnawy T, El-Said T. Acute respiratory tract infections among Hajj medical mission personnel, Saudi Arabia. *International Journal of Infectious Diseases*. 2007;11(3).
30. Balaban V, Stauffer WM, Hammad A, Afgarshe M, Abd-Alla M, Ahmed Q, et al. Protective practices and respiratory illness among US travelers to the 2009 Hajj. Vol. 19, *Journal of Travel Medicine*. 2012.
31. Choudhry AJ, Al-Mudaimigh KS, Turkistani AM, Al-Hamdan NA. Hajj-associated acute respiratory infection among hajjis from Riyadh. *Eastern Mediterranean Health Journal*. 2006;12(3–4).

32. Alqahtani AS, Tashani M, Heywood AE, Almohammed ABS, Booy R, Wiley KE, et al. Tracking Australian Hajj Pilgrims' Health Behavior before, during and after Hajj, and the Effective Use of Preventive Measures in Reducing Hajj-Related Illness: A Cohort Study. *Pharmacy (Basel)* [Internet]. 2020 May 4 [cited 2023 Aug 9];8(2):78. Available from: <https://pubmed.ncbi.nlm.nih.gov/32375320/>
33. Emamian MH, Hassani AM, Fateh M. Respiratory tract infections and its preventive measures among Hajj pilgrims, 2010: A nested case control study. *Int J Prev Med*. 2013;4(9).
34. Goumballa N, Hoang VT, Diouf FS, Mbaye B, Parola P, Sokhna C, et al. Risk factors for symptoms of infection and the acquisition of pathogens among pilgrims at the Grand Magal of Touba, 2017–2021. *Travel Med Infect Dis*. 2022;49.
35. Hoang VT, Meftah M, Anh Ly TD, Drali T, Yezli S, Alotaibi B, et al. Bacterial respiratory carriage in French Hajj pilgrims and the effect of pneumococcal vaccine and other individual preventive measures: A prospective cohort survey. *Travel Med Infect Dis*. 2019;31.
36. Hoang VT, Ali-Salem S, Belhouchat K, Meftah M, Sow D, Dao TL, et al. Respiratory tract infections among French Hajj pilgrims from 2014 to 2017. *Sci Rep*. 2019;9(1).
37. Mahdi HA, Qashqari FS, Hariri SH, Bamerdah S, Altayyar SA, Almalki HM, et al. Low Prevalence of Syndromic Respiratory Tract Infections among Returning Hajj Pilgrims Amidst the COVID-19 Pandemic: A Post-Hajj Survey. *Trop Med Infect Dis* [Internet]. 2022 Aug 1 [cited 2023 Aug 12];7(8). Available from: [/pmc/articles/PMC9413585/](https://pmc/articles/PMC9413585/)
38. Hashim HT, Babar MS, Essar MY, Ramadhan MA, Ahmad S. The Hajj and COVID-19: How the Pandemic Shaped the World's Largest Religious Gathering. *Am J Trop Med Hyg* [Internet]. 2021 Mar 1 [cited 2023 Aug 12];104(3):797. Available from: [/pmc/articles/PMC7941851/](https://pmc/articles/PMC7941851/)
39. Shaterian N, Abdi F, Kashani ZA, Shaterian N, Darvishmotevalli M. Facemask and Respirator in Reducing the Spread of Respiratory Viruses; a Systematic Review. *Arch Acad Emerg Med* [Internet]. 2021 Jan 1 [cited 2023 Aug 12];9(1):1–14. Available from: [/pmc/articles/PMC8464015/](https://pmc/articles/PMC8464015/)
40. Wang MX, Gwee SXW, Chua PEY, Pang J. Effectiveness of Surgical Face Masks in Reducing Acute Respiratory Infections in Non-Healthcare Settings: A Systematic Review and Meta-Analysis. Vol. 7, *Frontiers in Medicine*. 2020.
41. Tabatabaieizadeh SA. Airborne transmission of COVID-19 and the role of face mask to prevent it: a systematic review and meta-analysis. *Eur J Med Res* [Internet]. 2021 Dec 1 [cited 2023 Aug 12];26(1):1. Available from: [/pmc/articles/PMC7776300/](https://pmc/articles/PMC7776300/)
42. Li Y, Liang M, Gao L, Ayaz Ahmed M, Uy JP, Cheng C, et al. Face masks to prevent transmission of COVID-19: A systematic review and meta-analysis. *Am J Infect Control*. 2021;49(7).
43. Kesehatan Masyarakat J, Melviana Simatupang M, Veronika E, Sitepu O. Potential Self-contamination: Improper Hygiene Procedure of Using Masks. *Jurnal Kesehatan Masyarakat* [Internet]. 2021 Oct 12 [cited 2023 Aug 12];17(2):169–79. Available from: <https://journal.unnes.ac.id/nju/index.php/kemas/article/view/25627>
44. Rahimi Z, Mohammadi MJ, Araban M, Shirali GA, Cheraghian B. Socioeconomic correlates of face mask use among pedestrians during the COVID-19 pandemic: An ecological study. *Front Public Health*. 2022;10.
45. He W, Cai D, Geng G, Klug D. Factors Influencing Wearing Face Mask in Public During COVID-19 Outbreak: A Qualitative Study. *Disaster Med Public Health Prep*. 2023;17(8).
46. Kolewe EL, Stillman Z, Woodward IR, Fromen CA. Check the gap: Facemask performance and exhaled aerosol distributions around the wearer. *PLoS One* [Internet]. 2020 Dec 1 [cited 2023 Aug 12];15(12). Available from: [/pmc/articles/PMC7744055/](https://pmc/articles/PMC7744055/)
47. Dbouk T, Drikakis D. On respiratory droplets and face masks. *Physics of Fluids* [Internet]. 2020 Jun 6 [cited 2023 Aug 12];32(6):63303. Available from: [/pmc/articles/PMC7301882/](https://pmc/articles/PMC7301882/)



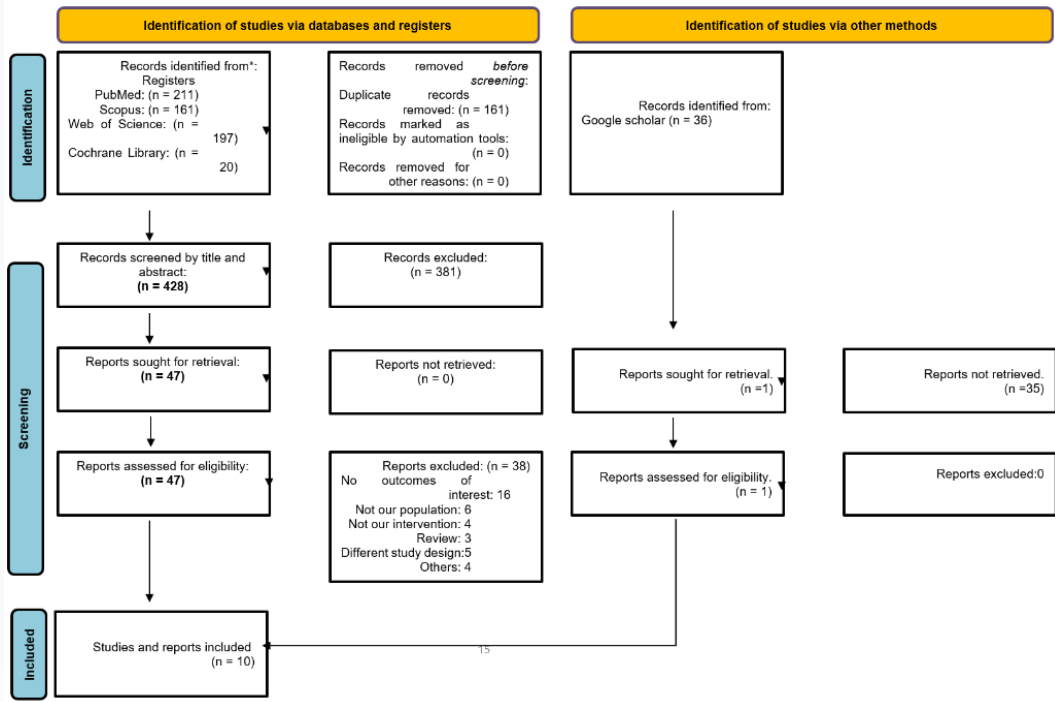
Table 1 summary of the studies included in this systematic review and meta-analysis.

Study ID	Study design	Country	Hajj year	Population	Sample size
Al-Asmary 2007 (30)	Nested case-control study	Saudi Arabia	2004	Hajj mission members of the Al-Hada and Taif Military Hospitals	250
Al-Jasser 2013 (1)	Prospective cohort	Saudi Arabia	2010	Hajj pilgrims sought their required pre-Hajj meningococcal vaccination.	1507
Alqahtani 2020 (33)	Prospective cohort	Australia	2015	Australian Hajj travelers	421
Balaban 2012 (31)	Prospective cohort	USA	2009	US pilgrims to the 2009 Hajj.	186
Choudhry 2006 (32)	Prospective cohort	Saudi Arabia	2002	Hajjis from Riyadh	1027
Emamian 2012 (34)	Nested case-control study	Iran	NR	Iranian pilgrims	95
Gautret 2015 (4)	Prospective cohort	France	2012–2014	French pilgrims participating in the Hajj between 2012-2014	382
Goumballa 2022 (35)	Prospective cohort	France	2017–2021	Pilgrims were from two villages (NDiop and Dielmo) located in the south of Senegal, in the Fatick region.	535
Hoang 2019 (36)	Prospective cohort	France	2015	French Hajj pilgrims	119
Hoang 2019 (2) (37)	Prospective cohort	France	2014-2017	French Hajj pilgrims	485

Table 2: Baseline characteristics of the included studies.

Study ID	Sample size	Age mean (SD)	Sex: male n (%)	First time Hajj n (%)	Presence of comorbidities (total) n (%)	Diabetes n (%)	Immunosuppression n (%)	Asthma n (%)	Other lung diseases n (%)	Type of face mask n (%)		
										Surgical face mask	N95 face mask	Others
Al-Asmary 2007 (30)	250	37 (8.73)	218 (87.2)	NR	NR	NR	NR	NR	NR	NR	NR	NR
Al-Jasser 2013 (1)	1507	37.9 (12.1)	930 (61.7)	NR	278 (18.4)	155 (55.7)	NR	32 (11.5)	NR	NR	NR	NR
Alqahtani 2020 (33)	421	42.2 (11.2)	229 (54)	NR	118 (28)	41(35)	1 (1)	33 (28)	2 (2)	NR	NR	NR
Balaban 2012 (31)	186	Mean = 48.9y (range 16–89)	92 (49.5)	NR	31 (16.7)	NR	NR	NR	NR	NR	NR	NR
Choudhry 2006 (32)	1027	33.5 (11.7)	750 (73.03)	NR	83 (8.1)	47 (4.6)	NR	16 (1.6)	NR	NR	NR	NR
Emamian 2012 (34)	95	<60: 54.7% >=60: 45.3%	55 (57.9)	NR	46 (48.4)	NR	NR	NR	NR	NR	NR	NR
Gautret 2015 (4)	382	Mean = 60.6y (range 22–85)	145 (38)	281 (73.6)	210 (55.1)	105 (27.5)	5 (1.3)	NR	NR	NR	NR	NR

Goumballa 2022 (35)	53 5	Median = 24y	270 (50.5)	NR	48 (8.9)	NR	NR	NR	NR	NR	NR	NR
Hoang 2019 (36)	11 9	Median [IQR]: 61 [52; 66]	62 (52.1)	106 (89.1)	NR	39 (32.8)	0 (0)	NR	12 (10.1)	NR	NR	NR
Hoang 2019 (2) (37)	48 5	40.9 (9.2)	136 (85)	NA	26 (14.7)	NR	NR	NR	NR	NR	NR	NR





## Vaccinations for Hajj: Enhancing Health and Global Health Security

Anas A. Khan<sup>1</sup>, Bander Balkhi<sup>2</sup>, Fahad A. Alamri<sup>3</sup>, Ghadah Alsaleh<sup>4</sup>, Hani Johkdar<sup>5</sup>

1-Global Center for Mass Gatherings Medicine, Ministry of Health, Department of Emergency Medicine, College of Medicine, King Saud University, 2-Department of Clinical Pharmacy, College of Pharmacy, King Saud University, 3-Global Center for Mass Gatherings Medicine, Ministry of Health, Riyadh, 4-Global Center for Mass Gatherings Medicine, Ministry of Health, 5-Deputyship of Public Health, Ministry of Health, Riyadh, Saudi Arabia.

\*Corresponding author: E-mail (Anaskhan@ksu.edu.sa)

## تطعيمات الحج: تعزيز الصحة والأمن الصحي العالمي

أنس خان<sup>1,2</sup>، بندر بلخي<sup>3</sup>، دكتور فهد العمري<sup>1</sup>، غادة الصالح<sup>1</sup>، هاني جوخدار<sup>4</sup>

1-المركز العالمي لطب الحشود، وزارة الصحة، الرياض، 2- قسم طب الطوارئ كلية الطب جامعة الملك سعود، 3- قسم الصيدلة الإكلينيكية، كلية الصيدلة، جامعة الملك سعود، 4- قسم الصحة العامة، وزارة الصحة، الرياض.

### الملخص

الخلفية: تشكل الأمراض المعدية خطراً كبيراً على الأمن الصحي العالمي، حيث يتم تسهيل انتقالها في كثير من الأحيان عن طريق التجمعات الجماهيرية. ويعتبر الحج مثالاً بارزاً على مثل هذه التجمعات، حيث يمثل واحدة من أكبر التجمعات (MGs) على مستوى العالم. تلعب التطعيمات دوراً حاسماً في التخفيف من انتقال الأمراض المعدية. هذا جهد لتوضيح دور التطعيمات في الحد من حدوث وانتقال الأمراض المعدية وتأثيرها على النظام المنسق عالمياً. الطرق: تتضمن هذه الدراسة مراجعة شاملة للأدبيات التي تركز على المقالات المتعلقة بالسياسات والممارسات المحيطة باللقاحات أثناء الحج. تم إجراء بحث شامل في قواعد البيانات الإلكترونية المختلفة، بما في ذلك PubMed، Scopus، وGoogle Scholar. النتائج: أظهرت جميع بروتوكولات التطعيم المطبقة في الحج، بما في ذلك التطعيم ضد التهاب السحايا بالمكورات السحائية والحمى الصفراء والأنفلونزا والمكورات الرئوية وكوفيد-19، فوائد كبيرة في السيطرة على انتشار العدوى. الاستنتاج: يجب على السلطات الصحية وواضعي السياسات خلال التجمعات الحاشدة فهم الدور الحيوي للقاحات الحج. يجب أن يستمر تنفيذ برنامج التحصين وتحسينه قبل التجمعات الحاشدة في المساهمة بشكل إيجابي في النظام المنسق عالمياً.

### Abstract

**Background:** Infectious diseases pose a substantial risk to global health security (GHS), with their transmission often exacerbated in mass gatherings (MGs). The Hajj pilgrimage is a prominent illustration of such gatherings, representing one of the largest and most diverse MGs (MGs) globally. Vaccinations play a crucial part in mitigating the transmission of infectious diseases. This is an effort to elucidate the role of vaccinations in reducing the incidence and transmission of infectious diseases and their implication on GHS.

**Methods:** This study entails a comprehensive literature review that focuses on articles pertaining to the policies, practices, and impact of Hajj vaccines. A comprehensive search was conducted in various electronic databases, including PubMed, Scopus, and Google Scholar.

**Results:** All vaccination protocols implemented in Hajj, including vaccination against meningococcal meningitis, Yellow Fever, Influenza and pneumococcal and COVID-19, have shown significant benefits in controlling the spread of infections.

**Conclusion:** Health authorities and policymakers during MGs must understand the vital role of vaccines. Immunization program implementation and improvement before MGs should continue to contribute positively to GHS.

**Keywords:** Hajj; Mass Gatherings; Vaccination; Global Health Security.

## 1. Introduction

Health security is a critical aspect of global public health, aiming to protect populations from threats such as infectious diseases, bioterrorism, and other health emergencies (1). Health security defined by as “the activities required, both proactive and reactive, to minimize the danger and impact of acute public health events that endanger people’s health across geographical regions and international boundaries” (2). It requires a comprehensive and collaborative approach to protecting public health across international boundaries and ensuring the community health worldwide. The concept acknowledges that health threats do not recognize national borders and can easily transcend geographical boundaries. As such, it necessitates a coordinated effort to strengthen healthcare systems’ resilience and protect communities’ well-being worldwide (3).

Infectious diseases have long posed significant threats to global health security (GHS), as they can rapidly spread across borders, affecting populations worldwide. Emerging infectious diseases have become increasingly prevalent over the past decades posing significant global health challenges (4). The ongoing emergence and reemergence of infectious diseases present a continuous challenge to healthcare systems and community well-being. Global interconnectedness, driven by international travel and trade, increases the risk of disease transmission and outbreaks (5). Recently, outbreaks of infectious diseases, such as SARS, Ebola, Zika, COVID-19, and others, have demonstrated the urgency of implementing robust public health strategies and international collaboration to curb their spread and mitigate their impact (6,7). Through vaccination, countries can build a protective shield against potential outbreaks and strengthen the resilience of healthcare systems in the face of health emergencies (8).

The gathering of a substantial number of individuals during mass gatherings intensifies the risk of infectious disease transmission among participants. This increased risk extends to the individuals present, the host country’s population, and even potentially impacts other countries through global travel, prompting substantial concerns for global health security (GHS) (9). One of the largest religious MGs worldwide is the Hajj pilgrimage in Saudi Arabia that attracts millions of pilgrims from over 180 countries (10). Historically, Hajj has been associated with the occurrence and dissemination of various infectious diseases, including respiratory tract infections, meningitis and (11). However, through strategic measures, the Hajj pilgrimage has shifted from a potential threat to a lasting legacy for GHS. Meticulous planning, enhanced surveillance, and robust public health strategies have transformed this significant mass gathering into a beacon of best practices in infectious disease prevention and control, contributing positively to global health security.

The Hajj health management is well known as a best health practice in mass gatherings globally and employs comprehensive public health planning and surveillance systems to monitor health risks and provide necessary health services (12,13). Saudi mitigation strategy effectively prioritized the well-being of pilgrims and healthcare personnel during the Hajj, effectively mitigating the potential transmission of COVID-19 and making a significant contribution to GHS (14,15). The Hajj vaccination policy is critical to Saudi Arabia’s approach to GHS, as it plays a pivotal role in preventing the spread of diseases and significantly reducing morbidity and mortality rates (16), (8). Incorporating vaccination as part of the broader GHS agenda is crucial in protecting populations worldwide from public health threats (17).

Understanding the role of Hajj vaccines in enhancing health security is crucial for policymakers, healthcare providers, and public health authorities involved in Hajj planning and management. This study aims to contribute to the existing knowledge by examining the impact of Hajj vaccination programs, evaluating the effectiveness of current strategies, and providing recommendations for optimizing health security measures during the pilgrimage. By exploring previous vaccination campaigns' experiences, successes, and challenges and analyzing available data and literature, this study seeks to inform evidence-based practices and policies to safeguard the health and well-being of Hajj pilgrims and the global community. Additionally, As the world continues to face emerging infectious disease threats, the valuable lessons from Hajj vaccination programs offer a crucial guide to bolster health security preparedness. These insights not only safeguard individuals locally and internationally but also hold broader implications for major events and global health crises. This underscores the necessity for countries to embrace strategic vaccination approaches, emphasizing the importance of proactive measures to reinforce health security. Through these efforts, nations can ensure the well-being and safety of their populations on both national and global scales.

## 2. Methods

This study focused on gathering and analyzing relevant literature on vaccination policies and practices during the Hajj pilgrimage and their implications for GHS. The aim was to understand the role of vaccination in preventing infectious disease transmission during MGs, such as Hajj, and its broader significance in strengthening GHS against infectious disease threats.

### 2.1. Literature Search

A comprehensive search was conducted in various electronic databases, including PubMed, Scopus, and Google Scholar. The search was conducted using appropriate keywords and terms related to "Hajj vaccination," "mass gatherings," "global health security," "infectious diseases," and "public health." The search was limited to articles published in English from Jan 2000 up to July 2023.

### 2.2. Inclusion and Exclusion Criteria

Articles were included in the review if they met the following criteria:

- Relevance to the topic of vaccination in the context of Hajj and its implications for GHS.
- Original research studies, systematic reviews, meta-analyses, and relevant review articles.
- Studies focusing on vaccination policies, strategies, and implementation during the Hajj pilgrimage and their impact on disease prevention.
- Studies exploring the effectiveness of vaccination in reducing infectious disease transmission during Hajj or other MGs.

Articles were excluded if they were:

- Not related to vaccination in the context of Hajj or GHS.
- Not published in English.
- Duplicates or irrelevant to the review objectives.

### 2.3. Data Extraction and Analysis

Two independent reviewers conducted the literature search and screened the titles and abstracts of the identified articles based on the inclusion and exclusion criteria. The full texts of the selected articles were then retrieved, and relevant data were extracted for analysis. The findings from the selected articles were analyzed to identify key themes and insights related to vaccination in Hajj and its impact on GHS.

### 2.4. Data Collection and Analysis:

The selected articles were thoroughly reviewed and analyzed to extract relevant information. The information obtained from the reviewed articles was synthesized and organized to provide a comprehensive overview of vaccination in the context of Hajj and its role in enhancing GHS.

## 3. Results

### 3.1. Saudi Arabia's Health Regulations and Vaccination Policies

Saudi Arabia's dedication to protecting the health and well-being of Hajj pilgrims is evident through its proactive and dynamic approach to implementing health regulations and vaccination policies. As the host country for the world's most complex and large annual pilgrimage, the Saudi Ministry of Health (MoH) plays a crucial role in creating a safe and secure environment for the millions of pilgrims who converge in the Holy Cities of Makkah and Madinah. To achieve this goal, the MoH has established a comprehensive and evolving set of guidelines and requirements for all individuals participating in the Hajj pilgrimage. Rigorous health regulations have been implemented at points of entry to protect public health and prevent the spread of infectious diseases. These policies encompass a range of health measures, including vaccination mandates, health screenings, and infectious disease surveillance. Regular updates and revisions to these regulations are undertaken to align with the dynamic nature of global health challenges and the prevalence of vaccine-preventable diseases (18). The comprehensive approach to health regulations at entry points reflects the Kingdom's commitment to GHS and proactive disease control measures (8).

### 3.2. Vaccination Requirements for the Hajj:

To control the spread of infectious diseases, Saudi Arabia mandates certain vaccinations for all pilgrims intending to participate in the Hajj. The review identified a range of vaccines commonly administered to pilgrims participating in the Hajj pilgrimage. These vaccines target infectious diseases that pose a significant health risk during MGs.

In response to the COVID-19 pandemic, stringent measures have been implemented (19–21), requiring visitors to present proof of a negative COVID-19 test before arrival (22). Additionally, preventive measures against Meningococcal disease have been enforced. Visitors from countries with a risk of yellow fever transmission must present a valid Yellow fever vaccination certificate upon entry. Similarly, Zika and Dengue prevention measures have been implemented, necessitating a certificate indicating vector control measures have been carried out before arrival (23).

The meningococcal meningitis vaccination is crucial for Hajj pilgrims due to the potential for the rapid spread of this disease in crowded settings. The Saudi MoH has made it mandatory for all pilgrims, including those from countries with low disease incidence, to receive the meningococcal vaccine before arriving in Saudi Arabia (24). This preventive measure has significantly lowered the incidence of meningococcal disease in Saudi Arabia from 1987 to 2015. Notably, Mecca reported zero cases from 2006 onward, marking a commendable milestone in disease control (25). This declining trend emphasizes the crucial role of continuous vaccination programs in preventing and managing meningococcal disease, contributing significantly to global health security, contributing to global efforts to control outbreaks. (26).

The vaccination requirements are aimed at protecting individual pilgrims and have a broader impact on GHS. By reducing the risk of disease transmission among the diverse population of pilgrims from various parts of the world, Saudi Arabia contributes to preventing the international spread of infectious diseases. Additionally, the vaccination policies promote herd immunity among pilgrims, protecting the pilgrims and the local and global communities they interact with during their journey.

Table 1: Required vaccines for pilgrims before Hajj season 2021 and 2022 (27)

	<i>Target population</i>	<i>Target countries</i>	<i>Approved vaccine</i>
SARS-COV-2 (COVID-19)	All travellers over 11 years intending to perform or attend Hajj	All countries	- Approved doses number by each type of vaccine(28)
Meningococcal meningitis	All individuals aged one year and over, arriving for Hajj or work in Hajj zones	All countries	- Quadrivalent (ACYW) polysaccharide vaccine within the last three years. - Quadrivalent (ACYW) conjugate vaccine within the last five years.
Poliomyelitis	All travellers	States reporting cases of WPV1 or cVDPV1 (Appendix 1-Table 1)	- At least one dose of bivalent oral polio vaccine (bOPV) or inactivated polio vaccine (IPV).
Poliomyelitis	All travellers	Countries reporting cVDPV2 positive Human Sources samples or Acute Flaccid Paralysis (AFP) case	- At least one dose of IPV3, if (IPV) is unavailable, it is acceptable to be vaccinated with at least one dose of the oral polio vaccine (OPV).
Yellow Fever	All travellers above nine months of age	Countries at risk of yellow fever transmission	- Yellow fever vaccine. The Yellow Fever vaccination certificate is valid for life, starting ten days after vaccination.
Poliomyelitis	All travellers	Countries reporting positive environmental sources samples of cVDPV2	- At least one dose of (IPV) 5, if (IPV) is not available, it is recommended to be vaccinated with at least one dose of the oral polio vaccine (OPV)
Seasonal Influenza	Travellers arriving for Hajj or seasonal work in Hajj areas, particularly pregnant women, children under five years, the elderly, and individuals with chronic disease conditions (such as chronic cardiac, pulmonary, renal, metabolic, neurodevelopmental, liver, or hematologic diseases) and individuals with immunosuppressive conditions.	Recommended for all countries & <i>Mandatory for Domestic pilgrims</i>	- Seasonal influenza vaccine

### 3.3. Effectiveness of vaccination in preventing infectious disease outbreaks during Hajj.

The effectiveness of vaccination in preventing infectious disease outbreaks during the Hajj is a critical aspect of GHS. Vaccination has played a vital role in curbing the transmission of vaccine-preventable diseases among pilgrims. Various studies have demonstrated the positive impact of vaccination in reducing the incidence of infectious diseases during the Hajj. For example, vaccination against meningococcal meningitis has successfully prevented outbreaks.

Invasive meningococcal disease (IMD) outbreaks linked to Hajj and Umrah pilgrimage events have been widely recognized. Past outbreaks have shown significant global spread of specific *Neisseria meningitidis* serogroups (29). The emergence of meningococcal serogroup W (MenW) raised global concern after the 2000/2001 Hajj outbreaks. The Saudi MoH nowadays requires all pilgrims to receive the quadrivalent meningococcal vaccine, which targets the ACWY serogroups. This proactive measure has significantly reduced the risk of meningitis outbreaks among the massive gathering of pilgrims. The results indicated a successful vaccination policy, as a significant decline in meningococcal disease cases was observed among Hajj pilgrims after introducing the quadrivalent meningococcal vaccine in Saudi Arabia (30,31). Another study by Memish et al. found that implementing compulsory meningococcal vaccination for pilgrims reduced the incidence of the disease (32). The prevalence of carriage and the antimicrobial resistance patterns observed highlight the need for effective preventive measures, including continuous surveillance and monitoring of meningococcal carriage and vaccination strategies, to enhance health security during the Hajj pilgrimage and mitigate the risk of disease transmission among the pilgrims and their communities. Understanding the prevalence and antimicrobial resistance patterns of *N. meningitidis* among pilgrims contributes to enhancing GHS and protecting public health during such events.

Similarly, vaccination against yellow fever has also played a crucial role in preventing its transmission during the Hajj. The vaccination requirement for pilgrims from yellow fever-endemic regions has been instrumental in preventing the spread of the disease and protecting both pilgrims and the local population. Additionally, implementing vaccination policies against other vaccine-preventable diseases, such as influenza and polio, was highly effective in reducing the risk of disease transmission and further bolstered health security during the Hajj. These vaccination campaigns have effectively mitigated the risk of outbreaks and ensured the safety and well-being of pilgrims.

### 3.4. Vaccination coverage and uptake

Among Hajj pilgrims, variations in vaccination uptake were evident based on their countries of origin. This demonstrated differences in vaccination uptake, necessitating targeted interventions and awareness campaigns to improve coverage and ensure the health of all pilgrims.

A cross-sectional study was conducted among Malaysian Hajj and Umrah pilgrims in 2018, and the study found that the uptake of influenza and pneumococcal vaccines among the pilgrims was relatively low, with only 28.6% receiving the influenza vaccine and 25.4% receiving the pneumococcal vaccine (33). Among the 527 pilgrims considered "at increased risk" of infections, only 31.9% of participants received the influenza vaccine, and 34.9% received the pneumococcal vaccine. This indicates that a significant proportion of high-risk individuals did not receive the recommended vaccines. This study's low and declining vaccination uptake raises concerns about unvaccinated pilgrims' potential health risks. Educating the pilgrims about the importance of vaccination and its role in protecting their health is essential to enhance vaccine uptake and ensure their well-being during MGs(34). Overall, efforts to enhance vaccine uptake among pilgrims are crucial in strengthening GHS during MGs and protecting the health of pilgrims and the wider community.

In a study conducted by Alfelali et al., most participants declared their influenza vaccination history, with 51.3% reporting that they received the influenza vaccine before their travel to Hajj. The study revealed a significant increase in vaccination rates over the years, indicating a positive trend in influenza vaccine uptake among Saudi Hajj pilgrims (35). The study's findings emphasize the importance of ongoing public health interventions to promote influenza vaccination and overcome barriers that hinder vaccine acceptance. By continuously educating and engaging Saudi Hajj pilgrims about





- **Reduced Healthcare Expenditures:** Vaccination significantly reduces the risk of infectious disease outbreaks among pilgrims during Hajj, which minimizes the burden on healthcare systems and associated costs. By preventing infections and related complications, healthcare resources can be directed more efficiently, reducing the strain on the healthcare system and minimizing medical costs (39).
- **Improved Productivity:** Healthy pilgrims are more likely to participate fully in the religious activities and rituals of the Hajj pilgrimage. By staying healthy, pilgrims can better engage in their spiritual journey, contributing to a more fulfilling and productive pilgrimage experience.
- **Improve Awareness and Health Education:** Vaccination campaigns during Hajj also serve as an opportunity to raise awareness about the importance of immunization and public health measures among pilgrims and healthcare providers. Promoting health education and emphasizing the significance of vaccination contribute to improved global health literacy and engagement in disease prevention efforts beyond the pilgrimage (42).
- **GHS:** Hajj vaccination efforts contribute to GHS by reducing the risk of disease transmission between countries. Preventing infectious disease outbreaks during the pilgrimage prevents the international spread of diseases and helps maintain the health security of the global community.
- **Long-Term Economic Growth and Sustainability:** The host country is committed to promoting a safe and healthy pilgrimage experience by investing in vaccination campaigns and public health measures during Hajj. This positive reputation enhances the country's image in the global community, attracting more pilgrims in the long run and fostering sustainable economic growth.
- **Strengthening Healthcare Infrastructure:** The focus on vaccination during Hajj drives attention and investment towards strengthening the host country's healthcare infrastructure and public health systems. This improvement benefits pilgrims during the pilgrimage and enhances the overall healthcare services available to the local population, leading to better health outcomes and increased economic productivity in the region.
- **Negating the need of days loss of work due to illness or quarantine.**

Table 2. Impact of Hajj Vaccination on GHS

Aspect	Impact of Hajj Vaccination
Disease Transmission Prevention	Vaccination reduces the risk of disease transmission among Hajj pilgrims, preventing outbreaks and limiting the spread of infectious diseases.
Global Disease Surveillance	Hajj vaccination helps monitor and track vaccine-preventable diseases, enhancing global disease surveillance and early detection.
Healthcare System Resilience	Vaccination supports healthcare systems in managing emergencies and preserving resources by reducing the burden of vaccine-preventable diseases.
International Collaboration	Mandatory vaccination for Hajj fosters international cooperation in ensuring health security and sharing best practices for disease prevention.
Public Health Education and Awareness	Vaccination campaigns for Hajj increase public health awareness, promoting a culture of proactive health measures within pilgrims' home countries.
Border Health Security	Vaccination safeguards borders and curtails the importation of infectious diseases, protecting GHS against potential threats.

### 3.7. Global Collaboration

Communicating with health authorities from different countries and sharing information about infectious disease trends ensures a coordinated and cohesive global response to potential health threats. This open exchange of knowledge and

expertise enhances preparedness and response capabilities, contributing to the overall success of health security efforts (43).

One of the key factors contributing to the success of vaccination efforts during the Hajj is the Saudi MoH comprehensive public health planning. It collaborates closely with international health organizations and leverages evidence-based practices to design effective vaccination campaigns. This strategic approach ensures that the most relevant and up-to-date vaccines are administered to pilgrims, enhancing the overall effectiveness of the vaccination programs.

Effective health security governance during the Hajj relies on seamless coordination and information sharing between international organizations, Saudi Arabian authorities, and relevant stakeholders. Regular communication channels are established to disseminate real-time updates on infectious disease outbreaks, emerging health risks, and best practices in health management. The successful implementation of vaccination strategies during the Hajj pilgrimage sets an example for other countries to follow in bolstering their health security frameworks.

### 3.8. Challenges and Successes in Implementing Vaccination Strategies

Despite the significant progress in vaccination efforts during the Hajj, challenges remain. Critical challenges were ensuring equitable access to vaccines, overcoming vaccine hesitancy, and addressing cultural and religious beliefs. Challenges also included logistical issues in reaching and vaccinating many pilgrims from diverse locations. Addressing vaccine availability and affordability barriers will further enhance health security during the Hajj. The review also emphasized the need for robust surveillance systems to monitor vaccine coverage and detect potential outbreaks promptly. On the other hand, successful vaccination campaigns demonstrated the importance of strong partnerships between health authorities, international organizations, and private sectors in coordinating and implementing vaccination programs effectively (42).

Table 3. Challenges and Strategies for Hajj Vaccination and GHS

Challenge	Strategies
Managing MGs	Implement crowd management techniques, enhance healthcare facilities, and establish medical centres to handle potential outbreaks.
Vaccine Supply and Distribution	Ensure an adequate supply of vaccines, establish distribution channels, and collaborate with manufacturers to meet demand.
Vaccine Hesitancy	Conduct public health campaigns to address misconceptions, provide education about vaccine benefits, and build trust in vaccination.
Cross-Border Disease Transmission	Strengthen disease surveillance and communication between countries, enforce vaccination requirements, and share health information.
Rapid Response to Emerging Outbreaks	Develop contingency plans, establish rapid response teams, and enhance collaboration with international health organizations.
Cultural and Religious Sensitivities	Engage religious leaders, integrate vaccination with religious teachings, and promote the importance of health in religious practices.
Health Equity and Access for Vulnerable Groups	Ensure access to vaccination for all pilgrims, especially vulnerable populations, through targeted vaccination programs and outreach.

### Discussion

The importance of GHS has become increasingly evident in the context of MGs, such as the Hajj (44). This comprehensive review reveals that Saudi Arabia has taken proactive measures to address health security concerns during the Hajj. Implementing mandatory vaccinations has significantly reduced the incidence of vaccine-preventable diseases among

pilgrims. Saudi Arabia's proactive measures, including mandatory vaccinations and comprehensive health regulations, have significantly reduced the incidence of vaccine-preventable diseases among pilgrims.

The experience gained from managing health security during the Hajj is invaluable in developing strategies for future MGs and health emergencies worldwide. The study emphasizes the need for ongoing collaboration and information sharing among countries to enhance global health resilience and preparedness. Lessons learned from the Hajj can inform long-term health security strategies, public health policies, and emergency response plans, contributing to improved global health systems' capacity to detect, prevent, and respond to infectious diseases (41).

Furthermore, the study's emphasis on the multidisciplinary approach echoes existing research highlighting the collaborative efforts needed to manage health security during MGs. Previous literature has emphasized the need for collaboration among healthcare professionals, policymakers, and researchers to develop comprehensive and practical health security strategies (45). Managing viral diseases like SARS and MERS during the Hajj has demonstrated the importance of timely and coordinated efforts between governments, health authorities, and international organizations in preventing disease transmission and safeguarding global health (38). Collaborative efforts from researchers, public health authorities, policymakers, and communities are essential to enhance data collection, research modelling, risk assessment, safety measures, and cultural awareness. By bridging these gaps and translating research findings into actionable measures, decision-makers can better equip themselves to protect public health and enhance GHS in the face of infectious disease challenges.

The knowledge and public health security gained through years of careful planning for the Hajj also contribute to KSA's broader vision for the future. With the Muslim population expected to grow globally, more pilgrims will travel to Mecca, aligning with Vision 2030. The lessons learned during the pandemic highlight the need for adaptability and agile vaccination strategies in handling emerging health threats (46). Saudi Arabia's commitment to evidence-based health regulations demonstrates its dedication to pilgrim safety and GHS standards, setting an example for other countries hosting MGs and reinforcing the importance of robust health security measures.

The findings of this study emphasize the importance of robust vaccination programs and international cooperation in ensuring the success of the Hajj pilgrimage while minimizing health risks. By addressing challenges such as vaccine hesitancy, monitoring vaccine safety, and integrating new vaccines and technologies, the health and global security of Hajj pilgrims can be further enhanced. Continued efforts in promoting vaccination and strengthening cooperation will contribute to a safer and healthier Hajj experience for pilgrims and support GHS. The cost-effectiveness of vaccination, the prevention of disease outbreaks, and the reduction in healthcare and economic burdens highlight the importance of incorporating health economics considerations into the planning and implementing Hajj vaccination strategies. By doing so, policymakers and stakeholders can ensure the sustainability of the pilgrimage's health security measures while maximizing the socio-economic benefits for all involved.

The study also highlights the evolving health security governance during the Hajj and the importance of continued efforts to improve vaccination coverage and compliance rates among pilgrims. Moreover, the experience of managing the Hajj during the COVID-19 pandemic underscores the need for adaptability and agility in health security planning to respond to rapidly changing circumstances effectively (47,48).

It is essential to acknowledge the potential limitations of this review, including possible publication bias and the exclusion of non-English language articles. Even though extensive literature searches, some relevant studies may have yet to be captured in the analysis. Additionally, the dynamic nature of infectious disease outbreaks and changing vaccination

recommendations may impact the relevance of the findings over time. Despite these limitations, efforts were made to ensure a comprehensive synthesis of the available literature on vaccination in Hajj and its implications for GHS. Future research should evaluate the long-term impact of vaccination strategies during the Hajj pilgrimage on GHS and explore innovative approaches to overcome vaccination-related challenges.

## Conclusion

Vaccination during the Hajj pilgrimage goes beyond individual health benefits; it offers substantial economic advantages and contributes significantly to GHS. By preventing disease outbreaks and reducing healthcare costs, vaccination enhances productivity and acts as a strategic defense against global health threats. Prioritizing vaccination efforts in Saudi Arabia not only ensures the well-being of pilgrims and the local community but also plays a crucial role in strengthening global health. This proactive approach reflects a wise investment with far-reaching impacts on health, economics, and global well-being.

## References:

1. Aldis W. Health security as a public health concept: a critical analysis. *Health Policy Plan* [Internet]. 2008;23(6):369–75. Available from: <https://doi.org/10.1093/heapol/czn030>
2. World Health Organization [Internet]. [cited 2023 Oct 9]. Health security. Available from: [https://www.who.int/health-topics/health-security#tab=tab\\_1](https://www.who.int/health-topics/health-security#tab=tab_1)
3. Rushton S. Global Health Security: Security for Whom? Security from What? *Polit Stud (Oxf)* [Internet]. 2011;59(4):779–96. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-9248.2011.00919.x>
4. Global Health and the Future Role of the United States [Internet]. *Global Health and the Future Role of the United States*. Washington, D.C.: National Academies Press; 2017. Available from: <https://www.nap.edu/catalog/24737>
5. Sönmez S, Wiitala J, Apostolopoulos Y. How complex travel, tourism, and transportation networks influence infectious disease movement in a borderless world. *Handbook of globalisation and tourism*. 2019;27–43.
6. Ventura D, di Giulio GM, Rached DH. Lessons from the Covid-19 pandemic: sustainability is an indispensable condition of Global Health Security. *Ambiente & Sociedade* [Internet]. 2020;23:1–13. Available from: <https://api.semanticscholar.org/CorpusID:226754534>
7. Flahault A, Wernli D, Zylberman P, Tanner M. From global health security to global health solidarity, security and sustainability. Vol. 94, *Bulletin of the World Health Organization*. Switzerland; 2016. p. 863.
8. Alotaibi BM, Yezli S, Bin Saeed AAA, Turkestani A, Alawam AH, Bieh KL. Strengthening health security at the Hajj mass gatherings: characteristics of the infectious diseases surveillance systems operational during the 2015 Hajj. *J Travel Med*. 2017 May;24.(3)
9. Alahmari AA, Khan AA, Alamri FA, Almuzaini YS, Alradini FA, Almohamadi E, et al. Hajj 2021: Role of mitigation measures for health security. *J Infect Public Health*. 2022 Sep ;
10. Alqahtani AS, Alfelali M, Arbon P, Booy R, Rashid H. Burden of vaccine preventable diseases at large events. *Vaccine*. 2015 Nov;33(48):6552–63.
11. Petersen E, Memish ZA, Zumla A, Maani A Al. Transmission of respiratory tract infections at mass gathering events. *Curr Opin Pulm Med*. 2020 May;26(3):197–202.
12. Al-Tawfiq JA, Gautret P, Benkouiten S, Memish ZA. Mass Gatherings and the Spread of Respiratory Infections. Lessons from the Hajj. *Ann Am Thorac Soc*. 2016 Jun;13(6):759–65.
13. Bieh KL, Khan A, Yezli S, El Ganainy A, Asiri S, Alotaibi B, et al. Implementing the Health Early Warning System based on syndromic and event-based surveillance at the 2019 Hajj. *Eastern Mediterranean Health Journal*. 2020 Dec 1;26(12):1570–5.
14. Jokhdar H, Khan A, Asiri S, Motair W, Assiri A, Alabdulaali M. COVID-19 Mitigation Plans During Hajj 2020: A Success Story of Zero Cases. *Health Secur*. 2021 Apr 1;19(2):133–9.

15. Khan A, Almuzaini Y, Aburas A, Alharbi NK, Alghnam S, Al-Tawfiq JA, et al. A combined model for COVID-19 pandemic control: The application of Haddon's matrix and community risk reduction tools combined. *J Infect Public Health*. 2022 Feb;15(2):261–9 .
16. Andre FE, Booy R, Bock HL, Clemens J, Datta SK, John TJ, et al. Vaccination greatly reduces disease, disability, death and inequity worldwide. *Bull World Health Organ*. 2008;86(2):140–6 .
17. Katz R, Sorrell EM, Kornblet SA, Fischer JE. Global health security agenda and the international health regulations: moving forward. *Biosecur Bioterror*. 2014;12(5):231–8 .
18. Abd El Ghany M, Sharaf H, Hill-Cawthorne GA. Hajj vaccinations—facts, challenges, and hope. *Int J Infect Dis*. 2016 Jun;47:29–37 .
19. Yezli S, Khan A. COVID-19 social distancing in the Kingdom of Saudi Arabia: Bold measures in the face of political, economic, social and religious challenges. *Travel Med Infect Dis*. 2020 Sep;37:101692 .
20. Memish ZA, Ahmed QA, Schlagenhauf P, Doumbia S, Khan A. No time for dilemma: mass gatherings must be suspended. *The Lancet*. 2020 Apr;395(10231):1191–2 .
21. Yezli S, Khan A. COVID-19 pandemic: it is time to temporarily close places of worship and to suspend religious gatherings. *J Travel Med*. 2021 Feb 23;28 .(2)
22. Khan A, Alahmari A. Managing Hajj Mass Gathering Throughout the Pandemic. *Prehosp Disaster Med*. 2023 May 13;38(S1):s79–s79 .
23. Al-Tawfiq JA, Memish ZA. The Hajj 2019 Vaccine Requirements and Possible New Challenges. *J Epidemiol Glob Health*. 2019 Sep;9(3):147–52 .
24. Badahdah AM, Alghabban F, Falemban W, Albishri A, Rani Banik G, Alhawassi T, et al. Meningococcal Vaccine for Hajj Pilgrims: Compliance, Predictors, and Barriers. *Trop Med Infect Dis*. 2019 Oct;4 .(4)
25. Yezli S, Assiri AM, Alhakeem RF, Turkistani AM, Alotaibi B. Meningococcal disease during the Hajj and Umrah mass gatherings. *International Journal of Infectious Diseases*. 2016 Jun;47:60–4 .
26. Al-Tawfiq JA, Gautret P, Memish ZA. Expected immunizations and health protection for Hajj and Umrah 2018 —An overview. *Travel Med Infect Dis*. 2017;19:2–7 .
27. Health M of. MOH, Saudi Arabia. [cited 2023 Aug 23]. Health Requirements and Recommendations for Travelers to Saudi Arabia for Hajj – 1444h (2023). Available from: [https://www.moh.gov.sa/HealthAwareness/Pilgrims\\_Health/Documents/Hajj-Health-Requirements-English-language.pdf](https://www.moh.gov.sa/HealthAwareness/Pilgrims_Health/Documents/Hajj-Health-Requirements-English-language.pdf)
28. Health) (Ministry of. MOH, Saudi Arabia. 2023 [cited 2023 Aug 23]. Vaccinations for Pilgrim's from Outside the Kingdom. Available from: [https://www.moh.gov.sa/en/HealthAwareness/Pilgrims\\_Health/Approved-Vaccines/Pages/Outside-the-Kingdom.aspx](https://www.moh.gov.sa/en/HealthAwareness/Pilgrims_Health/Approved-Vaccines/Pages/Outside-the-Kingdom.aspx)
29. Yezli S, Yassin Y, Mushi A, Bukhari M, Banasser T, Khan A. Carriage of Neisseria meningitidis Among Umrah Pilgrims: Circulating Serogroups and Antibiotic Resistance. *Infect Drug Resist*. 2022 Aug;Volume 15:4685–96 .
30. Yezli S. The threat of meningococcal disease during the Hajj and Umrah mass gatherings: A comprehensive review. *Travel Med Infect Dis*. 2018;24:51–8 .
31. Badur S, Khalaf M, Öztürk S, Al-Raddadi R, Amir A, Farahat F, et al. Meningococcal Disease and Immunization Activities in Hajj and Umrah Pilgrimage: a review. *Infect Dis Ther*. 2022 Aug;11(4):1343–69 .
32. Memish Z, Al Hakeem R, Al Neel O, Danis K, Jasir A, Eibach D. Laboratory-confirmed invasive meningococcal disease: effect of the Hajj vaccination policy, Saudi Arabia, 1995 to 2011. *Eurosurveillance*. 2013 Sep 12;18 .(37)
33. Goni MD, Naing NN, Hasan H, Wan-Arfah N, Deris ZZ, Arifin WN, et al. Uptake of Recommended Vaccines and Its Associated Factors Among Malaysian Pilgrims During Hajj and Umrah 2018. *Front Public Health*. 2019;7:268 .
34. Alamri FA, Amer SA, Alhraiwil NJ. Knowledge and practice after health education program among Hajj 1438 H (2017) pilgrims. *Saudi Arabia J Epidemiol Health Care*. 2018;1(1):7 .
35. Alfelali M, Barasheed O, Badahdah AM, Bokhary H, Azeem MI, Habebullah T, et al. Influenza vaccination among Saudi Hajj pilgrims: Revealing the uptake and vaccination barriers. *Vaccine*. 2018 Apr;36(16):2112–8 .

36. Haseeb A, Saleem Z, Faidah HS, Saati AA, AlQarni A, Iqbal MS, et al. Threat of Antimicrobial Resistance among Pilgrims with Infectious Diseases during Hajj: Lessons Learnt from COVID-19 Pandemic. *Antibiotics*. 2023 Aug 8;12(8):1299 .
37. Khan K, Memish ZA, Chhabra A, Liauw J, Hu W, Janes DA, et al. Global Public Health Implications of a Mass Gathering in Mecca, Saudi Arabia During the Midst of an Influenza Pandemic. *J Travel Med*. 2010 Mar 1;17(2):75–81 .
38. Niu S, Xu M. Impact of Hajj on Global Health Security. *J Relig Health*. 2019 Feb;58(1):289–302 .
39. Aminuddin F, Zaimi NA, Mohd Nor Sham Kunusagaran MSJ, Bahari MS, Mohd Hassan NZA. Cost-effectiveness and budget impact analysis of PPV23 vaccination for the Malaysian Hajj pilgrims. *PLoS One*. 2022 Jan 24;17(1):e0262949 .
40. Kim SY, Goldie SJ. Cost-Effectiveness Analyses of Vaccination Programmes. *Pharmacoeconomics*. 2008;26(3):191–215 .
41. Khan AA, Alamri FA, Alahmari AA, Almuzaini YS, Al Omary SA, Jokhdar HA. Historical Evolution and the Future of Global Health Security. *Journal of Nature and Science of Medicine [Internet]*. 2022;5(4). Available from: [https://journals.lww.com/jnsm/fulltext/2022/05040/historical\\_evolution\\_and\\_the\\_future\\_of\\_global.3.aspx](https://journals.lww.com/jnsm/fulltext/2022/05040/historical_evolution_and_the_future_of_global.3.aspx)
42. Goni MD, Hasan H, Wan-Arfah N, Naing NN, Deris ZZ, Arifin WN, et al. Health Education Intervention as an Effective Means for Prevention of Respiratory Infections Among Hajj Pilgrims: A Review. *Front Public Health*. 2020 Sep 3;8 .
43. Memish ZA, Zumla A, Alhakeem RF, Assiri A, Turkestani A, Al Harby KD, et al. Hajj: infectious disease surveillance and control. *The Lancet*. 2014;383(9934):2073–82 .
44. Memish ZA, Stephens GM, Steffen R, Ahmed QA. Emergence of medicine for mass gatherings: lessons from the Hajj. *Lancet Infect Dis*. 2012 Jan;12(1):56–65 .
45. Khorram-Manesh A, Burkle FM. Emergencies and Public Health Crisis Management-Current Perspectives on Risks and Multiagency Collaboration. 2020 ;
46. Williams J, Degeling C, McVernon J, Dawson A. How should we conduct pandemic vaccination? *Vaccine*. 2021 Feb;39(6):994–9 .
47. Khan Anasand Alsofayan YAAA/AAAHAJJH. COVID-19 in Saudi Arabia: the national health response. 27(11):1114–24 .
48. Alahmari AA, Khan AA, Alamri FA, Almuzaini YS, Habash AK, Jokhdar H. Healthcare policies, precautionary measures and outcomes of mass gathering events in the era of COVID-19 pandemic: Expedited review. *J Infect Public Health*. 2023 Mar;



## Medical Convoy: Interfacility Transfer of Patients during Mass Gathering Event

Anas A. Khan<sup>1&2</sup>, Haytham A. Sheerah<sup>3</sup>, Fahad A. Alamri<sup>2</sup>, Ghadah Alsaleh<sup>2</sup>, Yasir Almuzaini<sup>2</sup>, Ahmed A. Alahmari<sup>2</sup>, Nomai N. Mukhtar<sup>2</sup>, Mariyyah Alburayh<sup>2</sup>, Lamis Alabdullatif<sup>2</sup>, Bandar S. Almutairi<sup>4</sup>, Jalal M Alowais<sup>5</sup>, Hani Johkdar<sup>2</sup>

1-Department of Emergency Medicine, College of Medicine, King Saud University, 2-Global Center for Mass Gatherings Medicine, Ministry of Health, Ministry of Health, 3-Ministry of Health, Riyadh, 4-Emergency Medicine, Presidency of State Security, 5- Department of Surgery, College of Medicine, Imam Mohammad Ibn Saud Islamic University.

\*Corresponding author: E-mail (hjohkdar@moh.gov.sa)

## المرضى المنقولون بالقوافل الطبية إلى المشاعر خلال موسم الحج

### المخلص

خلاصة الخلفية: يجتمع ملايين المسلمين سنويًا في مكة المكرمة بالمملكة العربية السعودية لأداء فريضة الحج. تحتاج العديد من الحالات الطبية إلى رعاية متخصصة عند نقلها خارج المستشفى. تعتبر القافلة الطبية أسلوبًا جديدًا لنقل المرضى الداخليين وتقديم الرعاية خارج المستشفى. هدفت هذه الدراسة إلى وصف الحالات الطبية التي تنقلها القافلة الطبية بسيارات الإسعاف المجهزة إلى المشاعر المقدسة عرفة بمكة المكرمة خلال موسم الحج 2019. الطرق: تم استخراج بيانات المرضى عبر نموذج تقييم إلكتروني موحد. قام الأطباء المعالجون بالتشخيص الأولي في المستشفى. النتائج: من بين 274 مريضًا تم نقلهم، كان 36.1% من كبار السن (<60 عامًا)، و55.8% من الرجال، و59.9% من الآسيويين، و23% من الأفارقة. وكانت التشخيصات الأولية هي أمراض القلب والأوعية الدموية (26.3%)، وأمراض الجهاز التنفسي (18.2%)، والكسور (15.7%)، وأمراض الجهاز الهضمي (14.6%)، وأمراض الجلد والأنسجة تحت الجلد (10.3%)، والأمراض العصبية (8.3%). بالإضافة إلى ذلك، ساهمت الأمراض المصاحبة في 57.7% من الحالات، و32.5% لمرض السكري، و25.5% لأمراض الجهاز الهضمي.

الاستنتاجات: نجحت القافلة الطبية في نقل عدد كبير من المرضى المنومين، برفقة فرق طبية، وتقديم خدمات رعاية صحية عالية الجودة، للمشاركة في مناسك الحج. هذه الخبرة الطبية المبتكرة لديها القدرة على الاستفادة منها في أي حدث تجمع جماهيري قادم. ساهمت أمراض القلب والأوعية الدموية والجهاز التنفسي والتمثيل الغذائي والجهاز الهضمي والكسور في معظم الحالات الطبية المنقولة.

### Abstract

**Background:** Millions of Muslims gather annually in Makkah, Saudi Arabia, for Hajj pilgrimage. Several medical conditions need specialized care when transferred outside the hospital. The medical convoy is a novel approach for both the transportation of inpatients and the delivery of out-of-hospital care. This study aimed to describe medical conditions transferred by the medical convoy in well-equipped ambulances to the holy place Arafah in Makkah during the Hajj season 2019.

**Methods:** Patients' data were extracted via a standardized electronic evaluation form. The treating physicians made the primary diagnoses in the admitting hospital.

**Results:** Out of 274 transferred patients, 36.1% were older adults (>60 years), 55.8% were men, 59.9% were Asians, and 23% were Africans. The primary diagnoses were cardiovascular diseases (26.3%), respiratory diseases (18.2%), fractures



(15.7%), gastrointestinal diseases (14.6%), skin and subcutaneous tissue diseases (10.3%), and neurological diseases (8.3%). In addition, comorbidities contributed to 57.7% of cases, 32.5% to diabetes mellitus, and 25.5% to gastrointestinal diseases.

**Conclusions:** The medical convoy successfully handled the transportation of a significant number of inpatients, accompanied by medical teams and providing high-quality healthcare services, to participate in the Hajj rituals. This innovative medical expertise has the potential to be leveraged in any forthcoming mass gathering event. Cardiovascular, respiratory, metabolic, and gastrointestinal diseases and fractures contributed to most transferred medical conditions.

**Keywords:** Hajj; Mass Gatherings; EMS; Medical Convoy; Patients Transportation; Interfacility Transfer

## 1. Introduction

To fulfil patients' wishes aiming to complete Hajj rituals, assure patients' safety and provide the best evidence-based practice available, the Ministry of Health (MoH) in Saudi Arabia organizes a medical convoy annually to transfer admitted pilgrims from hospitals in different cities to the Holy Sites in Arafat, outskirts of Makkah, to ensure completing Hajj while providing optimal healthcare (1). Hajj, the annual Islamic pilgrimage to Makkah, is Islam's fifth and final pillar. It is one of the largest mass gatherings (MGs) in the world, with millions of Muslims from different countries converging in one place (up to more than three million pilgrims from more than 183 countries)(38).

One of the most potential health risks during the season of Hajj is the spread of infectious diseases, such as the flu and pneumonia providing the nature of the Congested mobile mass and the close contact with other pilgrims (2–8). In addition, heat-related illnesses, Food- and water-borne diseases, trauma and fractures particularly during the stoning ritual in Mina, all constitute a good portion of health risks (9,11). For socio-economic reasons, older adults represent a significant proportion of pilgrims, making them vulnerable to developing complications from their chronic medical conditions. Among these complications, cardiovascular diseases evolved as the major cause of mortality among pilgrims (12). While most medical conditions can be treated and released at the healthcare facilities distributed across different sites where the Hajj rituals are held, other medical conditions require admitting the pilgrim, and to complete his ritual, many are transferred by the medical convoy in well-equipped ambulances highly organized from different sites all to Arafat. This convoy has a specialized medical team consisting of physicians, nurses, and paramedics, standby ambulances, an intensive care ambulance, an integrated oxygen cabin, a mobile-first aid workshop, and a bus for transporting patient companions. In such context, this study aimed to describe the transferred medical conditions to complete their rituals in Makkah during the Hajj season 2019.

## 2. Methods

This descriptive cross-sectional study included transferred patients from Makkah hospitals by the medical convoy in well-prepared ambulances to Arafat during the Hajj season 2019. Medical convoy is a unique service provided by Saudi MoH to pilgrims on annual bases. This service uses specification guides in patients' inclusion criteria for safety and continuous health care services (Box 1). In the 2019 Hajj season, Patients' data were extracted via a standardized electronic evaluation form used to collect data from the pilgrims by trained healthcare workers from the medical convoy. Pilgrims from nearby cities of Jeddah and Taif are usually a handful, while 20-40 patients are usually brought from Madinah over more than 460 km. This study included patients transferred from Makkah City only. Inclusion criteria were all pilgrims admitted to the Makkah hospitals. In contrast, exclusion criteria were intubated patients, clinically unstable patients who score seven or more based on The National Early Warning Score (NEWS), or more than one inotrope medication, and patients with infectious diseases requiring isolation or contact precautions. This form included data about age, sex,

nationality, primary diagnosis, and comorbidities. The treating physicians made the primary diagnoses in the hospital where the patients were admitted. Quantitative data were presented as median and interquartile range. When appropriate, categorical data were presented as frequency and percentage analyzed using the Chi-square test or Fisher's exact test. A two-tailed P value <0.05 was considered statistically significant. The odds ratio with 95% CI was calculated to identify the predictive factors associated with different comorbidities. Statistical analysis was done by SPSS version 28 (IBM et al., USA).

**Box 1: Summary of medical instructions to transferred patients through medical convoy**

- The transfer procedure will be explained to the patient (informed consent).
- Pre-transfer assessment will be done by the inpatient admitting attending physician (consultant or senior registrar).
- Patients will be assessed and prepared for transport.
- The medical team for each transferred patient includes Emergency Medical Team, Nurse, and physician.
- The transport physician will take an appropriate handover from the admitting team.
- Accompanying personnel depend on the nature of the underlying illness, comorbidity, level of dependency and risk of deterioration during transfers:
  - Intensivists
  - Emergency physicians
- Ongoing reassessment throughout transport. Vital signs and mental status will be assessed and recorded periodically as indicated by the patient's condition during transportation.
- Any significant patient condition changes during transport must be reported to the transport medical director. This includes but is not limited to:
  - Deviation from the patient's typical vital signs
- Bedside assessment with transferring Nurse/RT to include:
  - Assessment of IV site, line patency, fluid rates, and monitor the line for any signs of infiltration.

**3. Results** This study included 274 transferred patients during the Hajj season 2019, within whom there was a slight male predominance (55.8%). More than one-third of patients (36.1%) were over 60. The most patients was Asian, accounting for (55.5%) of them, followed by African (23%), then Middle Eastern (18.2%), as shown in **Table 1**, Error! Reference source not found.

Table 1: Demographic data (n=274)

	N	%
<b>Age (years)</b>		
≤40	32	11.7
41-50	42	15.3
51-60	101	36.9
>60	99	36.1
Median (IQR)	60 (50 – 66)	
<b>Gender</b>		
Male	153	55.8
Female	121	44.2
<b>Nationality</b>		
African	63	23.0
Asian	152	55.5
Middle eastern	50	18.2
Others	9	3.3

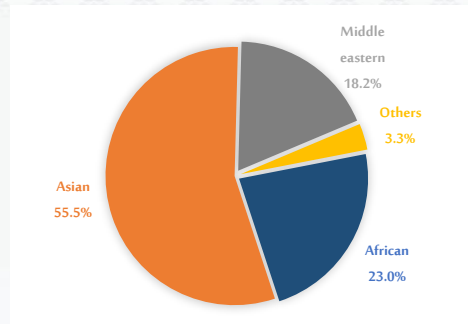


Figure 1: Nationality of the studied patients

Table 2: Diagnosis of the studied patients at admission (n=274)

Diagnosis	N	%
Cardiovascular diseases	72	26.3
Respiratory diseases	50	18.2
Fractures	43	15.7
Gastrointestinal diseases	40	14.6
Skin and subcutaneous tissue diseases	18	6.6
Neurological diseases	13	4.7
Mental disorders	10	3.6
Endocrine and metabolic diseases	7	2.6
Genitourinary diseases	6	2.2
Unspecified symptoms and signs	6	2.2
Infectious diseases	3	1.1
Hematological diseases	3	1.1
Malignant neoplasms	3	1.1

Regarding the primary diagnosis, the most frequently detected one among the studied patients was cardiovascular diseases at 26.3%, respiratory diseases at 18.2%, fractures at 15.7%, and gastrointestinal diseases at 14.6%, as shown in Table 2, Figure

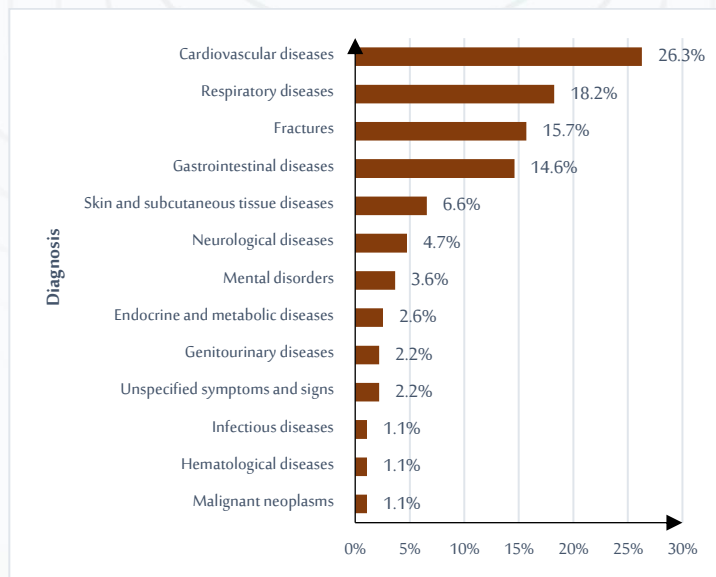


Figure 2: Diagnosis of the studied patients at admission

Table 3: Comorbidities of the studied patients (n=274)

Comorbidities	N	%
No	116	42.3
Yes	158	57.7
DM	89	32.5
HTN	70	25.5
CHF	12	4.4
CRF	7	2.6
CVA	6	2.2
COPD	6	2.2
CKD	5	1.8
Asthma	5	1.8
Schizophrenia	4	1.5
Cardiomyopathy	2	0.7
Bipolar	2	0.7
IHD	1	0.4
Oral neoplasm	1	0.4
Metabolic disorder, unspecified	1	0.4
Renal transplanted	1	0.4
Anaemia	1	0.4
SVT	1	0.4
Thyroid disease	1	0.4
Sickle cell disease	1	0.4

DM: Diabetes mellitus, HTN: Hypertension, CHF: Congestive heart failure, CRF: Chronic renal failure (Dependence on renal dialysis), CVA: Cerebral vascular accident, COPD: Chronic obstructive pulmonary disease, CKD: Chronic kidney disease, IHD: Ischemic heart disease, SVT: Supraventricular tachycardia

As presented in Error! Reference source not found., more than half of patients (57.7%) had comorbidities manifested by DM in approximately one-third of all patients (32.5%), HTN in 25.5%, CHF in 4.4%, CRF in 2.6%, CVA and COPD each in 2.2%, CKD and asthma each in 1.8%. [Error! Reference source not found.].

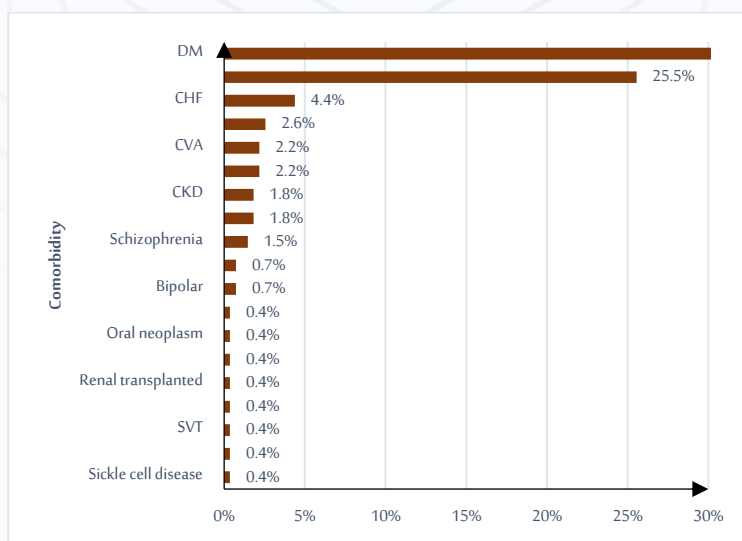


Figure 3: Type of comorbidities among the studied patients

Table 4: Association between the age of patients and different comorbidities

	Age (years)		P value	OR (95%CI)
	≤60 (n=175)	>60* (n=99)		
No	69 (39.4%)	47 (47.5%)	0.195	1.39 (0.84 to 2.28)
Yes	106 (60.6%)	52 (52.5%)		
DM	61 (34.9%)	28 (28.3%)	0.264	1.36 (0.79 to 2.32)
HTN	44 (25.1%)	26 (26.3%)	0.838	0.94 (0.54 to 1.66)
CHF	7 (4%)	5 (5.1%)	0.762	0.78 (0.24 to 2.54)
CRF	3 (1.7%)	4 (4%)	0.258	0.414 (0.09 to 1.89)
CVA	5 (2.9%)	1 (1%)	0.423	2.88 (0.33 to 25.03)
COPD	3 (1.7%)	3 (3%)	0.671	0.56 (0.11 to 2.82)
CKD	4 (2.3%)	1 (1%)	0.657	2.29 (0.25 to 20.8)
Asthma	3 (1.7%)	2 (2%)	>0.999	0.85 (0.14 to 5.15)
Schizophrenia	4 (2.3%)	0 (0%)	0.3	5.22 (0.28 to 98)
Cardiomyopathy	2 (1.1%)	0 (0%)	0.537	2.87 (0.14 to 60.33)
Bipolar	2 (1.1%)	0 (0%)	0.537	2.87 (0.14 to 60.33)
IHD	0 (0%)	1 (1%)	0.361	0.19 (0.01 to 4.64)
Oral neoplasm	1 (0.6%)	0 (0%)	>0.999	1.71 (0.07 to 42.39)
Metabolic disorder, unspecified	0 (0%)	1 (1%)	0.361	0.19 (0.01 to 4.64)
Renal transplanted	1 (0.6%)	0 (0%)	>0.999	1.71 (0.07 to 42.39)
Anaemia	1 (0.6%)	0 (0%)	>0.999	1.71 (0.07 to 42.39)
SVT	0 (0%)	1 (1%)	0.361	0.19 (0.01 to 4.64)
Thyroid disease	0 (0%)	1 (1%)	0.361	0.19 (0.01 to 4.64)
Sickle cell disease	1 (0.6%)	0 (0%)	>0.999	1.71 (0.07 to 42.39)

\*: The reference category, OR: Odds ratio, CI: Confidence interval, Statistical significance at P value<0.05

There was no statistically significant association between the age of the studied patients and different comorbidities, as shown in Table 4, Figure

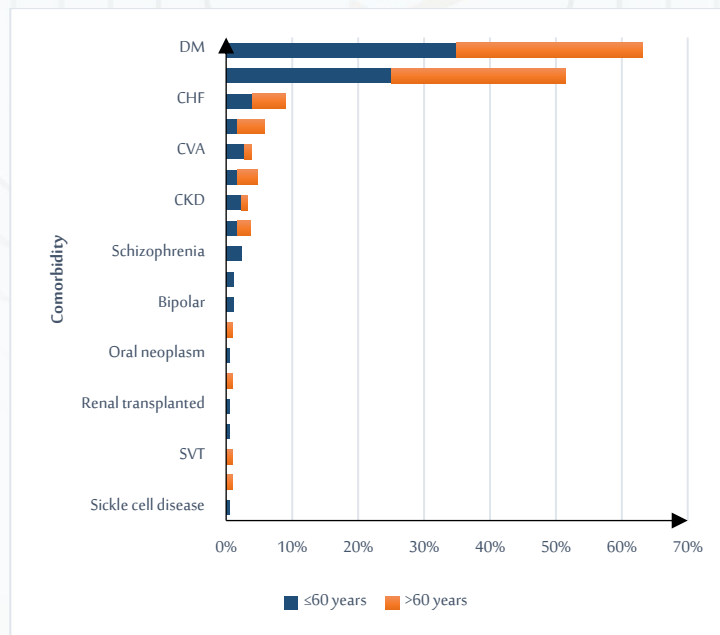


Figure 4: Comorbidities of the studied patients according to age

Table 5: Association between gender of patients and different comorbidities

	Gender		P value	OR (95%CI)
	Male (n=153)	Female* (n=121)		
No	71 (46.4%)	45 (37.2%)	0.125	0.68 (0.42 to 1.11)
Yes	82 (53.6%)	76 (62.8%)		
DM	41 (26.8%)	48 (39.7%)	<b>0.024</b>	<b>0.56 (0.33 to 0.93)</b>
HTN	38 (24.8%)	32 (26.4%)	0.762	0.92 (0.53 to 1.59)
CHF	9 (5.9%)	3 (2.5%)	0.172	2.46 (0.65 to 9.29)
CRF	4 (2.6%)	3 (2.5%)	>0.999	1.06 (0.23 to 4.81)
CVA	4 (2.6%)	2 (1.7%)	0.697	1.6 (0.29 to 8.87)
COPD	6 (3.9%)	0 (0%)	<b>0.036</b>	10.71 (0.6 to 192.01)
CKD	1 (0.7%)	4 (3.3%)	0.174	0.19 (0.02 to 1.74)
Asthma	4 (2.6%)	1 (0.8%)	0.338	3.22 (0.36 to 29.2)
Schizophrenia	2 (1.3%)	2 (1.7%)	>0.999	0.79 (0.11 to 5.68)
Cardiomyopathy	0 (0%)	2 (1.7%)	0.194	0.16 (0.01 to 3.27)
Bipolar	0 (0%)	2 (1.7%)	0.194	0.16 (0.01 to 3.27)
IHD	0 (0%)	1 (0.8%)	0.442	0.26 (0.01 to 6.48)
Oral neoplasm	1 (0.7%)	0 (0%)	>0.999	2.39 (0.1 to 59.2)
Metabolic disorder, unspecified	1 (0.7%)	0 (0%)	>0.999	2.39 (0.1 to 59.2)
Renal transplanted	0 (0%)	1 (0.8%)	0.442	0.26 (0.01 to 6.48)
Anaemia	0 (0%)	1 (0.8%)	0.442	0.26 (0.01 to 6.48)
SVT	1 (0.7%)	0 (0%)	>0.999	2.39 (0.1 to 59.2)
Thyroid disease	0 (0%)	1 (0.8%)	0.442	0.26 (0.01 to 6.48)
Sickle cell disease	1 (0.7%)	0 (0%)	>0.999	2.39 (0.1 to 59.2)

\*: The reference category, OR: Odds ratio, CI: Confidence interval, Statistical significance at P value<0.05

**Table 5** shows that the prevalence rate of DM was significantly lower in males compared to females (26.8% vs 39.7%, P=0.024) with significantly lower odds (OR=0.56, 95%CI: 0.33 to 0.93). On the contrary, male participants had significantly higher rates of COPD than females (3.9% vs. 0%, P=0.036).

#### 4. Discussion

For many years, transferring hospitalized pilgrims who need specialized care has been challenging mission that Saudi MoH proud of (13). Medical convoy is a unique experience worldwide that facilitates hospitalized patients to attend MG events at a specific time. This experience approaches hospital services outside the hospital for up to 24 hours. This cross-sectional study described the transferred patients with medical conditions by the medical convoy in well-equipped ambulances to complete their Hajj rituals in Arafat during the Hajj season 2019 (13,14). The results indicated that cardiovascular, respiratory, metabolic, and gastrointestinal diseases and fractures represented the most transferred medical conditions. In addition, at least a third of the transferred patients were older than 60, highlighting the importance of specialized geriatric care. The most prevalent nationality among studied patients was Asian, accounting for 55%, followed by African (23%), then Middle Eastern (18%).

Previous studies have reported various communicable and non-communicable diseases related to MG events. For instance, respiratory illnesses are common during MG events due to the proximity of people and the large crowds (15). Infectious agents such as influenza, coronavirus, and other respiratory viruses can quickly spread from person to person (16). Besides, gastrointestinal infections such as diarrhea and vomiting are common during mass gatherings due to contaminated food or water or poor hygiene practices (17,18). Further, skin infections such as impetigo and fungal

infections can be spread during Hajj due to crowded conditions and poor hygiene practices (9,19–22).

However, previous studies did not specify the medical conditions for transport in the medical convoy. This study illustrates the medical conditions successfully transferred and stay for hours in well-equipped health beds, which help similar future medical journeys in MG events. In the current study, the primary diagnosis, the most frequently detected among the studied patients, was cardiovascular disease at 26.3%, respiratory disease at 18.2%, fractures at 15.7%, and gastrointestinal disease at 14.6%.

Furthermore, the combination of high temperature and strenuous physical activity experienced during the Hajj rituals can result in heat exhaustion and dehydration, particularly among older persons, individuals with chronic diseases, and vulnerable individuals (23). Various measures have been implemented to reduce the risk of cardiovascular diseases among Hajj pilgrims, including providing medical screening and health education before and during the pilgrimage and promoting physical fitness and a healthy lifestyle (24). Accidents and attributed fractures are also common during mass gatherings events (25). However, fractures in older adults from minor injuries or falls indicate a high probability that fractures are related to osteoporosis (26,27). Hip and vertebral compression fractures are common types of fractures related to osteoporosis (28,29). In addition, Hajj rituals involve extended standing, walking, and strenuous physical activity, which can lead to musculoskeletal injuries, such as strains, sprains, and fractures. Early detection and management can reduce the risk of osteoporotic-related fractures (30) and mitigate the socio-economic effects of long-term disabling patients (31).

Our current study results showed that over a third of the transferred patients were older adults above 60 years old, with male predominance at 55.8%, considered among the most vulnerable populations during Hajj. Since the Hajj rituals in season 2019 took place in August when temperatures in Makkah reached 40°C, older adults were at a higher risk for major heat-related illnesses due to age-related changes in their body's ability to regulate temperature. Elderly patients are also at a higher risk of cardiovascular diseases, especially during physical exertion and stress. Besides, Hajj attracts pilgrims worldwide, increasing the risk of exposure to infectious diseases such as upper and lower respiratory tract infections (32). Older adults are at a higher risk of developing complications from respiratory infections (33). Besides, older adults are more susceptible to dehydration due to decreased thirst sensation and kidney function (34). Inadequate hydration can lead to cardiovascular and renal diseases (35,36). In this study, more than half of the patients had comorbidities manifested by DM in approximately one-third of patients, followed by HTN in 25.5% and CHF in 4.4%.

Further, mass gatherings can be a physically and emotionally challenging experience, as some people may feel overwhelmed by the crowds and unfamiliar surroundings. In addition, the stress of the pilgrimage can exacerbate existing mental health conditions (9,37). Thus, it is essential for older adults to consult their healthcare provider before embarking on the Hajj and to take appropriate precautions to minimize the risk of health complications.

This study has some limitations to be considered. At first, we had no data about other sociodemographic characteristics that might have affected the incidence of certain diseases. In addition, patients reported data about comorbidities, making them vulnerable to report and recall forms of bias.

#### **Conclusion:**

Medical transportation and long-term out-of-hospital care pose significant challenges for the healthcare sector. However, this presents a promising prospect for hospitalized patients, particularly when such an opportunity to attend a MG event is rare and unlikely to be repeated. The aforementioned medical convoy successfully handled the transportation of a significant number of inpatients, accompanied by integrated medical teams and providing high-quality healthcare

services, to participate in the Hajj rituals. The aforementioned medical convoy experience demonstrated that diseases can be effectively mitigated through early prevention measures. Cardiovascular, respiratory, fractures, metabolic, and gastrointestinal diseases contributed to most of the medical conditions carried by the medical convoy in Makkah. Older adults represented more than a third of the transferred patients. Our findings highlight the need for medical screening of chronic diseases before Hajj, specifically among older adults. Preventable risk factors and early drug interventions before Hajj for disease complications such as osteoporosis, diabetes and hypertension contribute to reducing the number of cases. Also, future studies in a new transportation method for medical convoys should be studied and follow-up patients for more extended periods.

### **Funding**

No funding sources to declare.

### **Conflict of interest**

No conflict of interest to declare.

### **Ethical considerations**

The Institutional Review Board of the Minister of Health, Saudi Arabia, approved the study protocol.

### **Data availability**

Available upon reasonable request.

### **References**

1. Ministry of Health, Medical Convoy 2016, <https://www.moh.gov.sa/Ministry/MediaCenter/News/Pages/News-2016-09-11-003.aspx>. 2016 .
2. Salathé M, Kazandjieva M, Lee JW, Levis P, Feldman MW, Jones JH. A high-resolution human contact network for infectious disease transmission. *Proc Natl Acad Sci*. 2010;107(51):22020–5 .
3. Memish ZA. Health of the Hajj. *Science* (80- ). 2018;361(6402):533 .
4. Taibah H, Arlikatti S, Andrew SA, Maghelal P, DelGrosso B. Health information, attitudes and actions at religious venues: Evidence from hajj pilgrims. *Int J Disaster Risk Reduct*. 2020;51:101886 .
5. Memish ZA, Assiri A, Turkestani A, Yezli S, al Masri M, Charrel R, et al. Mass gathering and globalization of respiratory pathogens during the 2013 Hajj. *Clin Microbiol Infect*. 2015;21(6):571.e1-571.e8 .
6. Mushi A, Yassin Y, Khan A, Alotaibi B, Parker S, Mahomed O, et al. A Longitudinal Study Regarding the Health Profile of the 2017 South African Hajj Pilgrims. *Int J Environ Res Public Health*. 2021;18(7):3607 .
7. Al-Tawfiq JA, Gautret P, Memish ZA. Expected immunizations and health protection for Hajj and Umrah 2018 —An overview. *Travel Med Infect Dis*. 2017;19:2–7 .
8. Alqahtani AS, Tashani M, Heywood AE, Almohammed ABS, Booy R, Wiley KE, et al. Tracking Australian Hajj Pilgrims' Health Behavior before, during and after Hajj, and the Effective Use of Preventive Measures in Reducing Hajj-Related Illness: A Cohort Study. *Pharmacy*. 2020;8(2):78 .
9. Aldossari M, Aljoudi A, Celentano D. Health issues in the Hajj pilgrimage: a literature review. *East Mediterr Heal J*. 2019;25(10):744–53 .
10. Ahmed QA, Arabi YM, Memish ZA. Health risks at the Hajj. *Lancet*. 2006;367(9515):1008–15 .
11. Yezli S, Khan A, Bouchama A. Summer Hajj pilgrimage in the era of global warming: a call for vigilance and better understanding of the risks. *J Travel Med*. 2019;26(7):taz069–taz069 .
12. Al Shimemeri A. Cardiovascular disease in Hajj pilgrims. *J Saudi Hear Assoc*. 2012;24(2):123–7 .



13. Gazette S. 443 pilgrims taken to Arafat in ambulances [Internet]. 2012 [cited 2022 Mar 20]. Available from: <https://saudigazette.com.sa/article/20132>
14. Ministry of Health, Medical Convoy 2019, <https://www.moh.gov.sa/Ministry/MediaCenter/News/Pages/news-2019-09-08-015.aspx>. 2019 ;
15. Wilder-Smith A, Steffen R. Mass Gatherings. *Travel Medicine*. 2019. p. 383–6 .
16. Leung NHL. Transmissibility and transmission of respiratory viruses. *Nat Rev Microbiol* [Internet]. 2021;19(8):528–45. Available from: <https://doi.org/10.1038/s41579-021-00535-6>
17. Collender PA, Morris C, Glenn-Finer R, Acevedo A, Chang HH, Trostle JA, et al. Mass Gatherings and Diarrheal Disease Transmission Among Rural Communities in Coastal Ecuador. *Am J Epidemiol*. 2019 Aug;188(8):1475–83 .
18. Abubakar I, Gautret P, Brunette GW, Blumberg L, Johnson D, Poucherol G, et al. Global perspectives for prevention of infectious diseases associated with mass gatherings. *Lancet Infect Dis*. 2012 Jan;12(1):66–74 .
19. Mirza AA, Alsakkaf MA, Mohammed AA, Mirza AA, Elmorsy SA. Patterns of emergency department visits during Hajj period: Towards healthcare optimization in view of Saudi Arabia's vision 2030. *Pakistan J Med Sci*. 2019;35 .(3)
20. Yezli S, Mushi A, Almuzaini Y, Balkhi B, Yassin Y, Khan A. Prevalence of Diabetes and Hypertension among Hajj Pilgrims: A Systematic Review. *Int J Environ Res Public Health*. 2021;18(3):1155 .
21. Alamri FA, Khan A, Badokhan AH, Abogazalah FN, Alhraiwil NJ, Amer SA. Common health complains among pilgrims during Manasik El Hajj; Season 1439H (2018). *Merit Res J Med Med Sci*. 2020;8:351–60 .
22. Bakhsh AR, Sindy AI, Baljoon MJ, Dhafar KO, Gazzaz ZJ, Baig M, et al. Diseases pattern among patients attending Holy Mosque (Haram) Medical Centers during Hajj 1434 (2013). *Saudi Med J*. 2015;36(8):962–6 .
23. Abdelmoety DA, El-Bakri NK, Almowalld WO, Turkistani ZA, Bugis BH, Baseif EA, et al. Characteristics of Heat Illness during Hajj: A Cross-Sectional Study. *Biomed Res Int*. 2018;2018:5629474 .
24. Alamri FA, Amer SA, Alhraiwil NJ. Knowledge and Practice after Health Education Program among Hajj 1438 H (2017) Pilgrims. *Saudi Arab J Epidemiol Heal Care*. 2018;1(1):7 .
25. Koçak H, Tuncay İ. Evaluation of trauma cases in different types of mass gathering events. *Ulus travma ve acil cerrahi Derg = Turkish J trauma Emerg Surg TJTES*. 2022 Jun;28(6):781–9 .
26. Uusi-Rasi K, Karinkanta S, Tokola K, Kannus P, Sievänen H. Bone Mass and Strength and Fall-Related Fractures in Older Age. *J Osteoporos*. 2019;2019:5134690 .
27. Vaishya R, Vaish A. Falls in Older Adults are Serious. *Indian J Orthop*. 2020 Feb;54(1):69–74 .
28. Wong CC, McGirt MJ. Vertebral compression fractures: a review of current management and multimodal therapy. *J Multidiscip Healthc*. 2013;6:205–14 .
29. Kelly MA, McCabe E, Bergin D, Kearns SR, McCabe JP, Armstrong C, et al. Osteoporotic Vertebral Fractures are Common in Hip Fracture Patients and are Under-recognized. *J Clin Densitom Off J Int Soc Clin Densitom*. 2021;24(2):183–9 .
30. Tucci JR. Importance of early diagnosis and treatment of osteoporosis to prevent fractures. *Am J Manag Care*. 2006 May;12(7 Suppl):S181-90 .
31. Hernlund E, Svedbom A, Ivergård M, Compston J, Cooper C, Stenmark J, et al. Osteoporosis in the European Union: medical management, epidemiology and economic burden. A report prepared in collaboration with the International Osteoporosis Foundation (IOF) and the European Federation of Pharmaceutical Industry Associations (EFPIA). *Arch Osteoporos*. 2013;8(1):136 .
32. Benkouiten S, Charrel R, Belhouchat K, Drali T, Salez N, Nougairde A, et al. Circulation of respiratory viruses among pilgrims during the 2012 Hajj pilgrimage. *Clin Infect Dis*. 2013;57(7):992–1000 .
33. Yoshikawa TT, Norman DC, Grahn D. Infections in the aging population. *J Am Geriatr Soc*. 1985 Jul;33(7):496–503 .
34. Picetti D, Foster S, Pangle AK, Schrader A, George M, Wei JY, et al. Hydration health literacy in the elderly. *Nutr Heal aging*. 2017 Dec;4(3):227–37 .

35. Martínez García RM, Jiménez Ortega AI, Lorenzo-Mora AM, Bermejo LM. [Importance of hydration in cardiovascular health and cognitive function]. *Nutr Hosp.* 2022 Sep;39(Spec No3):17–20 .
36. Feehally J, Khosravi M. Effects of acute and chronic hypohydration on kidney health and function. *Nutr Rev.* 2015 Sep;73 Suppl 2:110–9 .
37. Alsofayan Y, Alamri F, Alradini F, Radwan N, Khan A, Alahmari A, et al. The impact of preventive measures on acute illnesses among pilgrims during Hajj season. *Saudi J Emerg Med.* 2021;218–24 .
38. Memish ZA, Stephens GM, Steffen R, Ahmed QA. Emergence of medicine for mass gatherings: lessons from the Hajj. *Lancet Infect Dis.* 2012 Jan;12(1):56-65. doi: 10.1016/S1473-3099(11)70337-1. PMID: 22192130; PMCID: PMC7185826.





## Factors Influencing Prognosis of Myocardial Infarctions During Hajj Season

Yosra A Turkistani<sup>1\*</sup>, Fatima Aboul enien<sup>2</sup>, Maryam Dahlawi<sup>3</sup>, Muhammad Aldabbag<sup>3</sup>, Rahaf I Bukhari<sup>3</sup>

1-Department of Medicine, Umm Al Qura University, Makkah, Saudi Arabia, 2-King Abdullah Medical City, Makkah, Saudi Arabia,

3-Faculty of Medicine, Umm Al Qura University, Makkah, Saudi Arabia.

\*Corresponding author: E-mail (yaturkistani@uqu.edu.sa)

## العوامل المؤثرة في توقعات النتائج للنوبات القلبية خلال موسم الحج

يسرى تركستاني<sup>1\*</sup>، فاطمة أبو العينين<sup>2</sup>، مريم دهلوي<sup>3</sup>، محمد الدباغ<sup>3</sup>، رهف بخاري<sup>3</sup>

1- قسم طب الباطنة، كلية الطب، جامعة أم القرى، 2- مدينة الملك عبدالله الطبية، 3- كلية الطب، جامعة أم القرى.

### المخلص

الهدف: هدفت هذه الدراسة إلى تقييم العلاقة بين السمات الديموغرافية والسريية والمختبرية مع التوقعات والنتائج لمرضى النوبة القلبية STEMI خلال موسم الحج لعام 2019م.

طريقة ومنهجية البحث: كانت هذه دراسة استعادية لمرضى STEMI في مدينة الملك عبدالله الطبية (KAMC) الذين أجروا تدخلاً تشريحياً أولياً لشريان التاج بالقسطرة في عام 2019م. وقد تم جمع جميع البيانات من السجلات الطبية بما في ذلك السمات الديموغرافية والأمراض المصاحبة والأمراض المزمنة والنتائج السريية والمختبرية وتفصيل نتائج المرضى.

النتائج: أظهرت نتائج السجلات وجود 324 مريض بـ STEMI، وجاءت أعمارهم بمتوسط عمر من 11 إلى 56 عاماً، وكان غالبيتهم من فئة الذكور حيث جاءت نسبتهم (83٪). كما بينت النتائج أن عدداً كبيراً من المرضى كانوا يعانون من زيادة في الوزن بنسبة (45.9٪) وهم ممن أتوا مناسك الحج وكانت نسبتهم (62٪). وكشفت نتائج الدراسة أن أكثر من نصف المرضى كانوا يعانون من داء السكري بنسبة (55٪) ومن يعانون من ارتفاع ضغط الدم بنسبة (59٪). وأظهرت النتائج أن عادة التدخين ووجود سابقة للإصابة كانت مرتبطة بشكل كبير بوفاة المرضى داخل المستشفى ( $p = 0.052$ ). بالإضافة إلى ذلك، كان القيام بالحج مرتبطاً بشكل كبير بوجود احتقان رئوي كمضاعفة ( $p = 0.054$ ). وكانت النتائج السيئة لمرضى STEMI مرتبطة بشكل كبير بمرض السكري وارتفاع ضغط الدم واضطرابات الدهون في الدم واضطرابات البوتاسيوم والصوديوم ( $p < 0.05$ ).

الخلاصة: أظهرت نتائج الدراسة ارتباطاً مهماً بين الأمراض المصاحبة السريية والنتائج السيئة لمرضى STEMI، مما يسلب الضوء على أهمية تحسين نمط الحياة وإدارة الأمراض المزمنة لجميع مرضى النوبة القلبية وأولئك الذين يتعرضون لخطر تطور المرض. علاوة على ذلك، وتؤكد النتائج على ضرورة زيادة الوعي بين أطباء الطوارئ في مكة المكرمة خلال موسم الحج بشأن الارتباط بين أداء فريضة الحج والنتائج السلبية لمرضى STEMI.

الكلمات الدالة: متلازمة ضيق الأوعية التاجية الحادة، نوبة قلبية، STEMI الحاجة.

## Abstract

**Aim:** This study aimed to assess the relationship between demographic, clinical and laboratory characteristics with prognosis and outcomes of STEMI patients.

**Method:** This was a retrospective for STEMI patients in KAMC Hospital undergoing primary percutaneous coronary intervention for in 2019. All the data collected from the medical records including demographics characteristics, comorbidities, chronic diseases, clinical and laboratory results, and detailed outcomes of patients.

**Results:** The registry included 324 STEMI patients, with an average age of  $56 \pm 11$  years and a majority being male (83%). A large number of patients were overweight (45.9%) and had completed Hajj pilgrimage (62%). More than half of the patients had diabetes (55%) and hypertension (59%). Smoking and a history of previous revascularization were significantly associated with in-hospital mortality ( $p=0.052$ ). Additionally, being a pilgrim was significantly associated with pulmonary edema as a complication ( $p=0.054$ ). Poor outcomes in STEMI patients were significantly associated with diabetes mellitus, hypertension, dyslipidemia, potassium and sodium abnormalities ( $p<0.05$ ).

**Conclusion:** Our study has found a significant correlation between clinical comorbidities and poor outcomes in STEMI patients, highlighting the importance of improving lifestyle and managing chronic diseases for all MI patients and those at risk of developing the disease. Furthermore, our findings underscore the need for heightened awareness among emergency physicians in Makkah during the Hajj season regarding the association between being a pilgrim and adverse outcomes in STEMI patients. Keywords: Acute coronary syndrome; myocardial infarction; STEMI; pilgrim; prognosis; outcomes.

## Introduction

ST-elevation myocardial infarction (STEMI) is a type of acute coronary syndrome (ACS) characterized by complete occlusion of a coronary artery, leading to ischemia and necrosis of the myocardium. STEMI is a serious medical condition that requires prompt diagnosis and intervention to reduce the risk of complications and mortality. According to the World Health Organization (WHO), cardiovascular diseases (CVDs) are the leading cause of death worldwide, accounting for 31% of all deaths globally in 2016 (1). In Saudi Arabia, CVDs are also a major health concern, accounting for 46% of all deaths in the country (2). Among CVDs, STEMI is a significant contributor to morbidity and mortality.

The prevalence of STEMI varies worldwide, with higher rates reported in developed countries. A systematic review of STEMI incidence and mortality rates in low- and middle-income countries (LMICs) reported a wide range of incidence rates, from 2.4 to 10.3 per 100,000 population per year, and mortality rates ranging from 4.5% to 24.8% (3). In Saudi Arabia, the reported incidence of STEMI varies between different regions and populations. A study conducted in the city of Jeddah reported an incidence rate of 5.1 per 10,000 person-years among the general population (4). Another study conducted in the Eastern Region of Saudi Arabia reported a higher incidence rate of 17.1 per 10,000 person-years among patients presenting to the emergency department with chest pain (5).

Diabetes mellitus is a common comorbidity among STEMI patients and has been associated with worse outcomes, including increased mortality and a higher risk of complications. A retrospective study conducted in China reported that diabetes mellitus was independently associated with a higher risk of in-hospital mortality and major adverse cardiovascular events among STEMI patients (6,7). Another study conducted in Qatar reported that diabetes mellitus was associated with a higher risk of adverse outcomes, including heart failure, cardiogenic shock, and mortality, among STEMI patients undergoing percutaneous coronary intervention (8,9).

The Hajj pilgrimage, which takes place annually in Makkah, Saudi Arabia, is a significant event that attracts millions of Muslims from around the world. The Hajj pilgrimage has been associated with an increased risk of various medical conditions, including cardiovascular diseases such as STEMI. Several studies have investigated the incidence and prevalence of STEMI among Hajj pilgrims. A study conducted in 2016 reported an incidence rate of 1.9 per 1000 pilgrims for STEMI during the Hajj season (10). Another study reported a higher incidence rate of 3.7 per 1000 pilgrims, with diabetes being the most common comorbidity among STEMI patients (11). The Hajj season in Makkah is a challenging time for healthcare providers due to the high volume of pilgrims and the increased risk of various medical conditions, including STEMI. Several studies have investigated the incidence and prevalence of STEMI among Hajj pilgrims and the associated risk factors and outcomes (12,13). However, more studies are needed to assess the impact of diabetes mellitus and other comorbidities in the prognosis of STEMI patients during Hajj season in Makkah, therefore, we conducted this study from KAMC Hospital in Makkah City as it is the only cardiothoracic center in Makkah which has a huge role during Hajj season. This study aimed to assess the relationship between demographic, clinical and laboratory characteristics with prognosis and clinical outcomes of STEMI patients.

## Results

A total of 329 STEMI patients undergoing primary percutaneous coronary intervention in KAMC Hospital were involved in this study. Table 1 is presenting the demographics characteristics of the patients as the mean age is 56±11, majority (83%) were male, more than half of the study sample were pilgrims and non-south Asians (62%) and (66%), respectively. Most of the patients (45.9%) had an overweight BMI between (25-29.9). Moreover, majority of patients had been presented early and are non-smokers. The laboratory characteristics of STEMI patients in this study are presented in Table 2, most of patients had a normal potassium and sodium level, however, a number of patients had abnormalities, as (7.6%) of them had mild hypokalemia and (14.9%) had mild hyponatremia. Furthermore, a few patients had moderate hyponatremia (2.1%) and mild hypernatremia (1.8%).

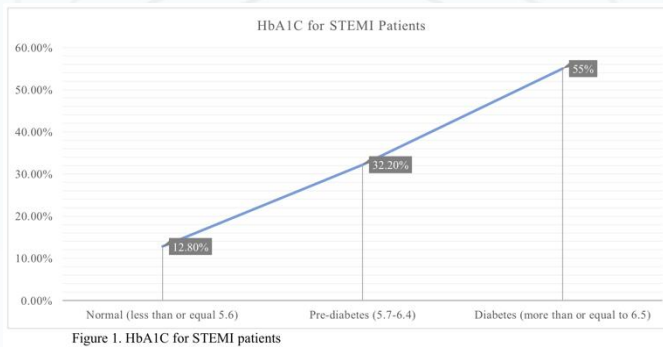
Table 1. Demographics characteristics of STEMI patients

Table 1. (N=329)				
Variables	Frequency	Percentage	Mean	Standard deviation
Age	-	-	56	±11
Male	273	83%	-	-
Female	56	17%	-	-
South Asians	112	34%	-	-
Non-South Asians	217	66%	-	-
Pilgrims	204	62%	-	-
Non pilgrims	125	38%	-	-
<b>BMI</b>				
Underweight <18.5	7	2.1%	-	-
Normal 18.5-24.9	95	28.9%	-	-
Overweight 25-29.9	151	45.9%	-	-
Obese 30-34.9	56	17%	-	-
Extremely obese >35	20	6.1%	-	-
<b>Early presentation</b>	271	82.4%	-	-
<b>Late presentation</b>	58	17.6%	-	-
<b>Smokers</b>	87	26.4%	-	-
<b>Non-smokers</b>	242	73.6%	-	-

Table 2. Laboratory characteristics of STEMI patients

Variables	Frequency	Percentage
<b>Potassium</b>		
Moderate hypokalemia	1	0.3%
Mild hypokalemia	25	7.6%
Normal	300	91.2%
Mild hyperkalemia	1	0.3%
Moderate hyperkalemia	1	0.3%
Severe hyperkalemia	1	0.3%
<b>Sodium</b>		
Moderate hyponatremia	7	2.1%
Mild hyponatremia	49	14.9%
Normal	263	79.9%
Mild Hypernatremia	6	1.8%
Moderate hypernatremia	4	1.2%
Severe hypernatremia	0	0%

Patients with STEMI often have diabetes mellitus as a common comorbidity (14), Therefore, HbA1C had been measured and the results are represented in Figure 1, as it shows that majority of patients (55%) are diabetic, (32.20%) are pre-diabetic, and only few patients (12.80%) are non-diabetic.



Regarding the clinical characteristics and associated comorbidities for STEMI patients in this study, majority of patients had diabetes mellitus (54.70%) and hypertension (59%).

Moreover, (30.70%) had dyslipidemia, (18.80%) are known ischemic heart disease patients (IHD), (9.10%) are on thrombolytic therapy, (8.50%) had a previous history of revascularization, and only (2.10%) of STEMI patients had a previous history of cerebrovascular accident (CVA), Figure 2 is showing further details. Figure 3 illustrates the complications and clinical outcomes experienced by STEMI patients at KAMC hospital.

It shows that a significant proportion of patients (58.90%) suffered from complications, with further details provided in Figure 4. Among these complications, (17.90%) of patients required an extended hospital stay of over a week, (9.40%) were intubated, (8.50%) experienced cardiac arrest, (7.90%) passed away in the hospital, and (7.60%) developed pulmonary edema or cardiogenic shock.

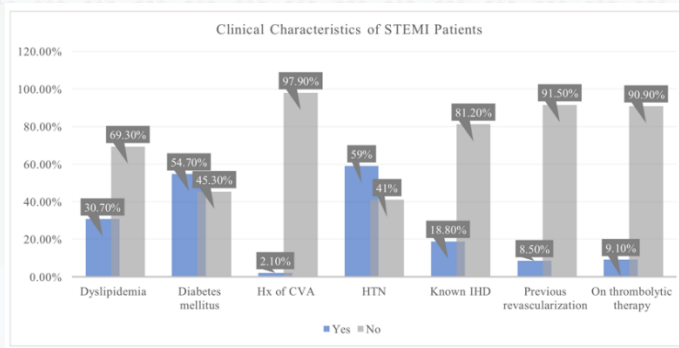


Figure 2. Clinical characteristics for STEMI patients

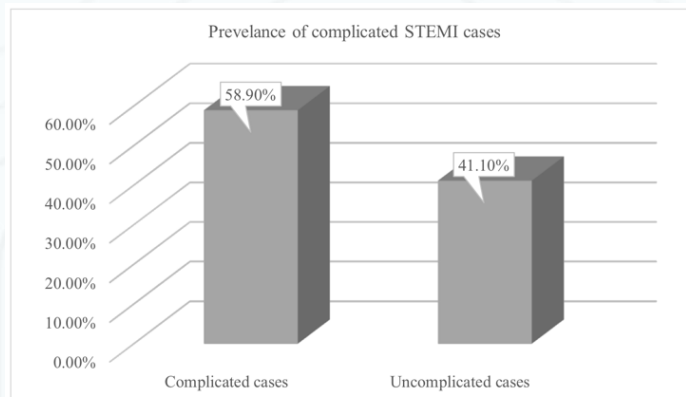


Figure 3. Summarized prevalence of complications among STEMI patients

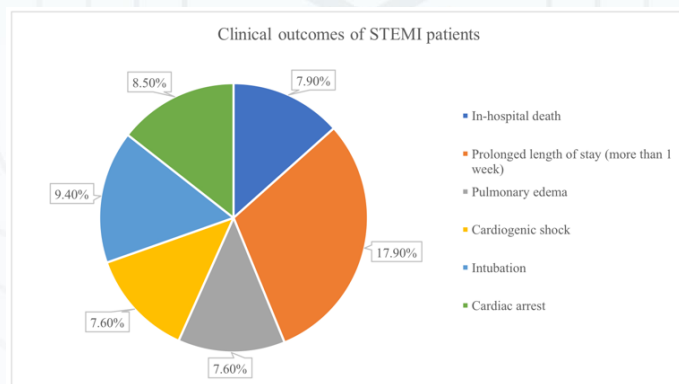


Figure 4. In-hospital clinical outcomes and complications in STEMI patients

Table 3 displays the correlation between demographic and clinical features of STEMI patients and their clinical outcomes. The findings indicate a noteworthy correlation between being a pilgrim with STEMI and experiencing pulmonary edema, with a statistically significant p-value ( $P=.054$ ). Additionally, smoking was found to have a correlation with in-hospital mortality among STEMI patients, with a p-value of ( $P=.052$ ). Abnormal potassium levels are linked to various complications in STEMI patients that can negatively impact their prognosis. These complications include in-hospital mortality ( $P=.013$ ), a hospital stay lasting more than one week ( $P=.006$ ), pulmonary edema ( $P=.021$ ), cardiogenic shock

(P=.002), intubation (P=.001), and cardiac arrest (P=.020). Furthermore, there is a significant correlation between sodium abnormalities and various outcomes in STEMI patients, including in-hospital mortality (P=.000), a hospital stays lasting more than one week (P=.000), pulmonary edema (P=.008), cardiogenic shock (P=.000), and cardiac arrest (P=.004). Dyslipidemia was also found to have a correlation with in-hospital mortality and intubation in these patients with a significant p-value (P=.027) and (P=.024), respectively. Patients with diabetes mellitus and STEMI have a notable correlation with pulmonary edema (P=.026), intubation (P=.056), and cardiac arrest (P=.008). STEMI patients with a history of cerebrovascular accident (CVA) have an association with in-hospital mortality (P=.040), cardiogenic shock (P=.034), and cardiac arrest (P=.055). Additionally, patients with STEMI and hypertension have a significant correlation with in-hospital mortality (P=.052), prolonged hospital stay for more than one week (P=.041), and intubation (P=.010). Patients diagnosed with STEMI and known ischemic heart disease (IHD) have a correlation with intubation, with a statistically significant p-value (P=.045). Patients who underwent revascularization in the past have a correlation with in-hospital mortality as a clinical outcome of STEMI (P=.006).

Table 3. Significant association between patient's characteristics and clinical outcomes

Characteristics	Clinical outcomes					
	In-hospital death	Prolonged hospital stay (> 1 week)	Pulmonary edema	Cardiogenic shock	Intubation	Cardiac arrest
	No. (P-value for the pearson's chi-square test)					
Pilgrims	—	—	20 (P=.054)	—	—	—
Smoking	3 (P=.052)	—	—	—	—	—
Potassium abnormalities	6 (P=.013)	6 (P=.006)	4 (P=.021)	6 (P=.002)	8 (P=.001)	6 (P=.020)
Sodium abnormalities	29 (P=.000)	12 (P=.000)	8 (P=.008)	8 (P=.000)	—	6 (P=.004)
Diabetic (HbA1C more than or equal 6.5)	—	—	19 (P=.058)	—	—	20 (P=.045)
Dyslipidemia	3 (P=.027)	—	—	—	4 (P=.024)	—
DM	—	—	19 (P=.026)	—	22 (P=.056)	22 (P=.008)
Hx of CVA	2 (P=.040)	—	—	2 (P=.034)	—	2 (P=.055)
HTN	20 (P=.052)	41 (P=.041)	—	—	25 (P=.010)	—
Known IHD	—	—	—	—	10 (P=.045)	—
Previous revascularization	6 (P=.006)	—	—	—	—	—

## Discussion

STEMI is a medical emergency that requires prompt intervention to reduce the risk of morbidity and mortality. It is a major global health concern and is recognized as the leading cause of death worldwide by the World Health Organization (WHO) (1). During the Hajj season, the workload at hospitals in the vicinity of Mecca, Saudi Arabia, increases significantly due to the influx of millions of pilgrims from all over the world. The Hajj season is a critical period for healthcare professionals as they face an increased number of patients with various medical conditions, including STEMI. The incidence of STEMI during the Hajj season has been reported to be higher than usual due to several factors, including physical exertion, dehydration, and emotional stress (6). Therefore, we conducted this study aiming to investigate the



impact of diabetes mellitus and other comorbidities in the prognosis of STEMI patients during Hajj season in Makkah city.

The research conducted on 324 STEMI patients and the results revealed that the average age of patients was  $56 \pm 11$  years and a majority of them were male (83%). Almost half of the patients were reported to be overweight (45.9%), and the majority of them were pilgrims (62%). In comparison to another study conducted in Makkah city between 2016 and 2019 to assess the incidence of STEMI (15), the demographics were found to be similar. The average age of patients in both studies was  $54 \pm 11$  years. However, there was a difference in the percentage of pilgrims in both studies. The previous study reported a lower percentage of pilgrims (32.2%) compared to the current study (62%). The male population in the previous study was found to be similar to the current study, with (88%) of patients being male. These findings highlight the importance of understanding the demographics of STEMI patients, particularly during the Hajj season when the number of pilgrims increases significantly. This information can aid healthcare providers in developing targeted interventions to prevent and manage STEMI among high-risk populations.

It is noteworthy that the study was conducted at a hospital located in the holy city of Makkah, where a significant portion of the patient population consisted of pilgrims. These individuals form a vulnerable group, comprising participants from various parts of the world with diverse risk profiles. The pilgrims engage in religious rituals in extremely stressful conditions, often in crowded and congested environments with millions of other pilgrims. Hajj pilgrimage is one of the largest mass gatherings in the world, with millions of pilgrims congregating in a confined space over a short period. This high-density environment can lead to physical and emotional stress, dehydration, and exhaustion, all of which are known risk factors for the development of STEMI (6). Furthermore, the crowded conditions during the Hajj can also lead to delays in medical care for pilgrims who experience STEMI. The sheer number of people in attendance can make it difficult for healthcare providers to navigate through the crowds and provide timely medical attention to those in need. This delay in care can exacerbate the severity of the condition and lead to poor clinical outcomes. In addition, the crowded conditions during the pilgrimage can also result in the spread of infectious diseases, which can further increase the risk of cardiovascular events, including STEMI. For example, respiratory infections, such as influenza, can increase the risk of cardiovascular events by triggering an inflammatory response and increasing the workload on the heart (16). Consequently, we investigated the prevalence of in-hospital clinical outcomes among STEMI patients with a comparison to another study conducted in Makkah city (15) which revealed similar results, as their study reported (4.6%) of patients with pulmonary edema, while our study found (7.60%). Furthermore, their study reported (6.9%) of patients with cardiogenic shock, while our study found (7.60%). In terms of intubation, their study reported (7.3%), while our study found (9.40%). Regarding cardiac arrest, their study reported (8.4%), while our study found (8.50%).

In conclusion, the presence of diabetes in patients who experience STEMI is associated with an increased risk of complications. Additionally, the occurrence of STEMI during the Hajj.

The current study also detected poor outcomes and prognosis associated with STEMI patients who had diabetes mellitus, hypertension, or hyperlipidemia as comorbidity as well as having history of CVA, previous revascularization, known to have IHD, or electrolytes abnormalities. Several mechanisms have been proposed to explain why STEMI patients with comorbidities are more prone to complications, including increased oxidative stress, inflammation, endothelial dysfunction, microvascular dysfunction, and platelet dysfunction (17). Among the comorbidities observed in our sample, Diabetes mellitus and hypertension were the most frequently encountered. thus, our results reported that diabetic patients with STEMI are correlated with pulmonary edema, intubation, and cardiac arrest ( $P=008$ ). When comparing our

results to another study published in the Journal of Diabetes and its Complications (18) reported that STEMI patients with DM had a higher incidence of heart failure, cardiogenic shock, and mortality compared to STEMI patients without DM. Pilgrimage increases the likelihood of complications. When diabetes is an associated actor to a STEMI during the Hajj season, the risk of complications is further heightened. It is important to note that the Hajj pilgrimage is a high-stress environment that can exacerbate the severity of cardiovascular events. The physical and emotional strain of the pilgrimage, along with the crowded conditions and potential exposure to infectious diseases, can increase the risk of complications for all pilgrims, but especially those with underlying health conditions such as diabetes. Therefore, it is crucial for healthcare providers to educate patients with diabetes who are planning to undertake the Hajj pilgrimage on the potential risks and to provide appropriate medical management and monitoring during the pilgrimage. Strategies such as early detection, prompt treatment, and aggressive management of diabetes and other comorbidities can help reduce the risk of complications and improve clinical outcomes. Additionally, it is important to have a well-coordinated emergency response system in place during the Hajj pilgrimage to ensure that patients with diabetes and other health conditions receive timely medical attention in the event of a cardiovascular event. This may include the provision of accessible medical facilities, trained healthcare staff, and efficient transportation systems to facilitate patient care. Moreover, emergency physicians in Makkah during the Hajj season should be aware of these risks and take appropriate measures to ensure the timely and effective management of STEMI patients. Additional research is required to assess the extent of knowledge and awareness among emergency physicians in Makkah regarding the appropriate management and actions to be taken for patients with cardiovascular emergencies.

### **Conclusion**

The results of our study emphasize the importance of managing clinical comorbidities and improving lifestyle for all MI patients, as well as those at risk of developing the disease. The presence of chronic diseases such as diabetes, hypertension, and hyperlipidemia were found to be significant risk factors for poor outcomes in STEMI patients. Therefore, efforts to prevent and manage these chronic diseases should be a priority in the management of MI patients. Furthermore, our study highlights the increased risk of adverse outcomes in STEMI patients during the Hajj season, particularly among pilgrims. Therefore, emergency physicians in Makkah during the Hajj season should be aware of these risks and take appropriate measures to ensure the timely and effective management of STEMI patients. Overall, our study adds to the growing body of evidence on the impact of clinical comorbidities and pilgrimage on the outcomes of STEMI patients. These findings underscore the need for a multidisciplinary approach to the management of MI patients, including efforts to improve lifestyle, manage chronic diseases, and enhance emergency medical services to reduce the burden of cardiovascular diseases in the population.

### **Recommendations**

These findings underscore the need for a multidisciplinary approach to the management of MI patients, including efforts to improve lifestyle, manage chronic diseases, and enhance emergency medical services to reduce the burden of cardiovascular diseases in the population.

### **References**

1. World Health Organization. (2018). Cardiovascular diseases (CVDs). Retrieved from [https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-\(cvds\)](https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds))
2. Ministry of Health. (2018). Saudi Health Council. Health statistical year book 1439H. Riyadh, Saudi Arabia.

3. Gupta, R., Gurm, H. S., Bartholomew, B. A., & Sharma, M. (2016). Low- and middle-income countries have disproportionately high burden of ST-elevation myocardial infarction. *International Journal of Cardiology*, 202, 9-13. <https://doi.org/10.1016/j.ijcard.2015.08.222>
4. Al-Khathlan, A., Al-Mohameed, A., & Al-Mazroa, M. (2012). Incidence of acute myocardial infarction in Jeddah, Saudi Arabia. *Journal of Epidemiology and Global Health*, 2(3), 141-147. <https://doi.org/10.1016/j.jegh.2012.07.003>
5. Al-Rubaish, A. M., Al-Zahrani, A. S., & Al-Najjar, Y. (2012). The incidence of acute coronary syndrome in a tertiary care center in Saudi Arabia: A retrospective cohort study. Page 10 of 18 *Journal of the Saudi Heart Association*, 24(4), 209-212. <https://doi.org/10.1016/j.jsha.2012.10.002>
6. Zhang, L., Zhao, Y., Wang, Y., Jiang, L., Guo, S., Wang, Y., ... & Gao, R. (2019). Diabetes mellitus and short-term outcomes in patients with acute myocardial infarction: A retrospective study. *Cardiovascular Diabetology*, 18(1), 151. <https://doi.org/10.1186/s12933-019-0961-x>
7. Al-Nozha, M. M., Al-Maatouq, M. A., Al-Mazrou, Y. Y., Al-Harhi, S. S., Arafah, M. R., Khalil, M. Z., ... & Al-Khadra, A. (2007). Diabetes mellitus in Saudi Arabia. *Saudi Medical Journal*, 28(3), 410-417.
8. Hachem, A., Alraies, M. C., Al-Dadah, A. S., Al Ali, H., Al-Khadra, Y., Al-Hawwas, M., ... & Alraies, M. (2017). Impact of diabetes mellitus on outcomes of patients undergoing percutaneous coronary intervention for ST-segment elevation myocardial infarction. *Journal of Interventional Cardiology*, 30(3), 257-262. <https://doi.org/10.1111/joic.12380>
9. Al-Harbi, S. S., Al-Mansour, M. R., Al-Backer, N. B., Al-Qahtani, S. S., Al-Harbi, A. S., & Al-Harbi, F. S. (2018). Diabetes mellitus and hypertension as risk factors for coronary artery disease in Saudi Arabia: A cross-sectional study. *PLoS One*, 13(10), e0206549. <https://doi.org/10.1371/journal.pone.0206549>
10. Alzeidan, R., Rabiee, F., Mandil, A., Hersi, A., Ullah, A., Asad, H., ... & Al-Malki, B. (2016). Incidence, risk factors and mortality of myocardial infarction in Hajj (Muslim pilgrimage) performers. *PLoS One*, 11(3), e01514147. <https://doi.org/10.1371/journal.pone.01514147>
11. Al-Amri, H. S., Al-Shehri, M., Al-Moghairi, A. M., Tamim, H. M., & Al-Faleh, H. F. (2012). The incidence and outcome of acute coronary syndrome during Hajj (pilgrimage to Mecca). *Hellenic Journal of Cardiology*, 53(3), 183-189. Page 11 of 18
12. Al-Homrani, H., Al-Hamid, A., Al-Mutairi, H., Alghamdi, M., & Al-Shahrani, F. (2018). Prevalence of cardiovascular risk factors among Hajj pilgrims: A systematic review and meta-analysis. *Journal of Epidemiology and Global Health*, 8(1-2), 69-77. <https://doi.org/10.2991/jegh.k.180531.001>
13. Bafail, A. O., Al-Khaffaf, H., Al-Jarallah, M., Al-Qurashi, S., Al-Ammar, H., & Al-Moghairi, A. (2019). Prevalence and predictors of cardiovascular diseases among Hajj pilgrims: A systematic review and meta-analysis. *Journal of Cardiology*, 74(4), 308-317. <https://doi.org/10.1016/j.jjcc.2019.04.010>
14. Cosentino, N., Bonomi, A., Campodonico, J., Veglia, F., De Ferrari, G. M., Genovese, S., & Marenzi, G. (2021). Can the in-hospital mortality gap between STEMI patients with and without diabetes mellitus be reduced? The cardio-renal hypothesis. *Nutrition, metabolism, and cardiovascular diseases : NMCD*, 31(5), 1516–1520. <https://doi.org/10.1016/j.numecd.2021.02.003>
15. Niazi, A. K., Kassem, H., Shalaby, G., Khaled, S., Alzahrani, M. S., Ali, H. M., & Aboulenein, F. (2021). Incidence and Predictors of Left Ventricular (LV) Thrombus after ST-Elevation Myocardial Infarction (STEMI) in the Holy Capital of Saudi Arabia. *Journal of the Saudi Heart Association*, 33(2), 101–108. <https://doi.org/10.37616/2212-5043.1243>
16. Kwong, J. C., Schwartz, K. L., Campitelli, M. A., Chung, H., Crowcroft, N. S., Karnauchow, T., ... & Buchan, S. A. (2018). Acute myocardial infarction after laboratory-confirmed influenza infection. *New England Journal of Medicine*, 378(4), 345-353. <https://doi.org/10.1056/NEJMoa1702090>
17. Chen, Y., Zhang, J., Li, X., & Luo, X. (2019). Diabetes mellitus and its impact on the pathogenesis and treatment of acute myocardial infarction. *Frontiers in Pharmacology*, 10, 1360. <https://doi.org/10.3389/fphar.2019.01360> Page 12 of 18

18. Li, J., Li, X., Wang, Q., Hu, S., Wang, Y., Masoudi, F. A., Spertus, J. A., Krumholz, H. M., & Jiang, L. (2017). ST-segment elevation myocardial infarction in China from 2001 to 2011 (the China PEACE-Retrospective Acute Myocardial Infarction Study): A retrospective analysis of hospital data. *The Lancet*, 390(10096), 2540- 2549. [https://doi.org/10.1016/S0140-6736\(17\)30754-9](https://doi.org/10.1016/S0140-6736(17)30754-9)



الملتقى العلمي الثالث والعشرون  
لأبحاث الحج والعمرة والزياره  
التميز المحدي في خدمة ضيوف الرحمن



جامعة أم القرى  
معهد خادم الحرمين الشريفين  
لأبحاث الحج والعمرة

## Theme of Preventive Health and Health Promotion for Pilgrims



## Assessing the factors associated with food labeling knowledge for pilgrim's during Hajj period

Huda Mohammed Mala Al-Barnawi

Department of Home Clinical Nutrition, Faculty of Applied Medical Sciences, Umm Al-Qura University

\*Corresponding author: E-mail (hmbarnawi@uqu.edu.sa)

### تقييم العوامل المرتبطة بمعرفة البطاقات الغذائية للحجاج خلال فترة الحج

هدى محمد مالا البرناوي

قسم التغذية الأكلينيكية، كلية العلوم الطبية التطبيقية، جامعة أم القرى

#### الملخص

من المهم جدًا زيادة وعي حجاج بيت الله الحرام بأهمية قراءة المعلومات الغذائية الموجودة على الأغذية، خاصة لكبار السن أو الأشخاص الذين يعانون من أمراض مزمنة مثل السكري وارتفاع ضغط الدم وذلك لتقليل المخاطر التي تنتج عن هذه الأمراض ولتقليل إنفاق وزارة الصحة على الخدمات الصحية. هدفت هذه الدراسة إلى تقييم معرفة الحجاج بالبطاقات الغذائية أثناء الحج. تم تسجيل الحجاج السعوديين وغير السعوديين (العدد = 1000، العمر  $\leq 35$  عامًا، رجال ونساء) في الفترة من 18 يونيو إلى 18 يوليو 2023. وتم جمع جميع البيانات باستخدام استبيان قوقل و حللت البيانات باستخدام الإصدار IBM SPSS Statistics 23.

هدفت هذه الدراسة إلى تقييم معرفة الحجاج واستخدامهم للمعلومات الغذائية الموجودة على الأطعمة أثناء فترة الحج. تظهر نتائجنا في أن (591) من إجمالي المشاركين (1000) كانوا من الرجال، و (563) من السعوديين. أغلب أفراد العينة كانوا من الحاصلين على درجة الماجستير/الدكتوراه جاءوا في المرتبة الأولى. جاء أفراد العينة الذين تتراوح أعمارهم من 46 سنة فأكثر في المرتبة الأولى، حيث كانوا أكثر وعياً بمعرفة أهمية قراءة الملصقات الغذائية من الأعمار الأخرى. كما أن الأفراد العاملين كانوا أكثر وعياً بمعرفة أهمية قراءة الملصقات الغذائية من العاطلين. وأظهرت النتائج أنه كلما ارتفع الدخل الشهري فإن الوعي بمعرفة أهمية قراءة الملصقات الغذائية يزداد، في حين لا توجد علاقة ارتباطية بين الجنسية والمعرفة بأهمية قراءة الملصقات الغذائية. وكذلك أوضحت النتائج أن التعليم كان من أكثر العوامل المؤثرة في معرفة أهمية قراءة الملصقات الغذائية بنسبة 84.3%، يليه العمر والوظيفة والجنس 74.2، 66.7، 63.1% على التوالي.

توصى هذه الدراسة بضرورة زيادة نشر الوعي بأهمية قراءة بطاقة المعلومات الغذائية للحجاج لمساعدتهم على اختيار طعامهم الصحيح لتقليل عوامل الخطر التي يمكن أن تسببها بعض الأمراض. حيث يمكن البدء بالتوعية قبل القدوم إلى المملكة العربية السعودية وأثناء فترة الحج من خلال توفير الأجهزة الذكية في العديد من الأماكن لقراءة البطاقات بعدة لغات لمن لا يستطيع القراءة.

#### Abstract

It is very important to raise awareness among pilgrims regarding the significance of reviewing nutritional labels on food. This is crucial, particularly for older individuals or those with chronic conditions like diabetes and hypertension. This is essential to minimize the risks associated with chronic diseases and to decrease healthcare expenses for the Saudi Ministry of Health (MOH).

This study aimed to assess pilgrims' knowledge of food labeling during Hajj. Saudi and non-Saudi pilgrims (n=1000, aged between  $\leq 35$  and  $\geq 46$  years, men and women) enrolled in this study from June 18 to July 18, 2023. All data were collected using an online self-reported questionnaire, using Google Forms. IBM SPSS Statistics 23 Version was used for data analysis.

Our result shows that (591) of the total participants (1000) were men, and (563) were Saudi while the education status of individuals who participated in this study with individuals who have a master's or Ph.D. being the highest, followed by a bachelor's and high school or diploma, respectively. Also individuals aged 46 years or more came in the first rank, where they were more aware of the knowledge of food labels, then those aged 35 to 45 years came in the second rank, and lastly, those whose age was less than 35 years old. The results also indicate that the employed were more aware of food labels than the unemployed. The results show that, if the monthly income gets higher, the awareness of the knowledge of food labels increases, while there is no correlation between nationality and the awareness of the knowledge of food labels. Also, there is no correlation between marital status and awareness of food labels. Also that education was one of the most influential factors in the knowledge of food labels by 84.3%, followed by age by 74.2%, followed by employment by 66.7%, and in the last rank, gender by 63.1%. Finally, the findings of the current results indicate that men are more aware than women of reading nutritional labels on food. Therefore, there is need for further research is carried out to educate the population on the importance of reading nutritional labels on food to keep themselves healthier particularly during Hajj period. This study recommended to increase the awareness of reading nutritional labeling information for Pilgrims to help them choose their correct food and reduce the risk factors that have the potential of causing some diet-related diseases. Spreading awareness could be initiated before the pilgrimage to Saudi Arabia and during the Hajj period by publishing brochures, giving educational lectures, teaching individuals how to read the labels, potential interpreters, and providing devices in many places to read the labels in several languages for those who are unable to read.

**Keywords:** Knowledge, Nutritional Labels, Saudi, Pilgrims, Hajj.

## 1. Introduction

In Islam, hajj is the fifth pillar, and it is an obligation once in a lifetime for those who are physically and financially able to perform it. The rites of Hajj are performed over five or six days, beginning on the eighth and ending on the thirteenth day of Dhu al-Hijjah, the last month of the Islamic calendar and it is expected that all pilgrims should be at the same places during the mentioned days (Saidovna, 2021). Based on the Hajj statistics publication, General Authority for Statistics, in 2022 the total number of internal and external pilgrims reached 926,062 and the percentage of external pilgrims reached 84.4% of the total pilgrims, with 781,409 pilgrims, which indicates that the Hajj is the largest human gathering in the world (Hajj statistics publication, General Authority for Statistics, 2022).

More than 2.5 million Muslims travel to Makkah each year from around 160 countries (Turkistani, 2022). It is crucial for pilgrims, especially older individuals and those with chronic diseases such as diabetes, hypertension, cardiovascular diseases, liver diseases, cancer, asthma, thyroid disorders, and iron deficiency (anemia), to be aware of the significance of reading nutritional labeling information. This awareness can help them make informed food choices and reduce the risk factors associated with these diseases. By emphasizing the importance of nutritional labeling information, pilgrims can take proactive steps to improve their health and well-being during their pilgrimage (Ahmed et al., 2019).

Despite the importance of awareness among pilgrims about the importance of reading nutritional labeling information, previous studies in this field are limited hence the reason why this study is important as the findings of our study could

help the Ministry of Hajj and Umrah, in cooperation with the Ministry of Health (MOH) to develop and provide meals that contain nutritional labeling information to pilgrims to take into account their health conditions and reduce the risk that results from some chronic diseases, as aforementioned.

Food labels can be defined as any tag, mark, pictorial, or other descriptive text, written or printed, attached to a pre-packaged food container (Al-Mughthem et al., 2020). Nutritional labeling information must display the amount of energy (calories and kilojoules) and the amount of fat, saturated fat, carbohydrates, sugars, proteins, and salt (all expressed in grams) present in 100g (or 100 ml) of the food (Food labelling -National Health Service inform, 2023). The four main sections of nutritional labeling information are highlighted in color, which are serving size information, calorie information, nutrient amounts, and percent daily values (MOH). The labels should list the allergens within the ingredients listed on the food labels. These labels can be effective instruments in helping consumers make healthy food choices (Food and Agriculture Organization of the United Nations, FAO).

Food Standards Australia New Zealand sets standards for what information must be on food labels. Some food labels provide information that relates to people's personal values and ethics, such as religious reasons (e.g., halal), animal welfare concerns, environmental concerns, or human rights issues (Labelling information for consumers-Food Standards Australia New Zealand,2023). The presence of protein from some foods, such as peanuts, milk, eggs, sesame seeds, fish and shellfish, soy, lupin, and wheat must be declared on the food label because food allergies can occur when a person's immune system reacts to allergens in these foods when they are present in food as ingredients (or as components of food additives or processing aids). The declaration of the food allergens in the labels, however small the amounts present, is lifesaving information for people allergic to these foods. (Allergen labelling for consumers-Food Standards Australia New Zealand, 2023).

Based on the Saudi Food and Drug Authority, a food label should contain the following information: food name, ingredients, nutritional information, food additives, allergens, warning statements, and storage and use instructions (Saudi Food and Drug Authority, 2019).

At present, several studies on nutritional labeling information have been conducted in developed countries such as the United States, the United Kingdom, and Ireland (Jáuregui et al., 2020). While no studies assessing pilgrim's knowledge of nutritional labeling information during the Hajj period have been conducted in Middle Eastern countries such as Saudi Arabia. Therefore, the main purpose of this study is to assess pilgrim's knowledge and use of nutritional labeling information during the Hajj period.

## 2. Methodology

This study aimed to assess the awareness and knowledge of nutritional labeling information during the Hajj period among Saudi and non-Saudi pilgrims aged between  $\leq 35$  and  $\geq 46$  years. The study comprised a structured questionnaire with 13 questions in both Arabic and English. The questionnaire was divided into two sections: The first section is: demographic characteristics, and the second section is: the usage of the information on food labels.

The survey was conducted from June 18 to July 18, 2023. All data were collected using an online self-reported questionnaire using Google Forms. The link to the online questionnaire was distributed to the target population (WhatsApp) groups and their responses were collected. The collected data (n= 1000) from participants was analyzed using IBM SPSS Statistics 23 Version. The reliability has been calculated by the Alpha-Cronbach coefficient and the split-half method.



### 3. Results and Discussion

#### The first hypothesis:

There are statistically significant differences among the mean degrees of the sample individuals in knowledge of food labels according to the study variables. To verify this hypothesis; the (T-test) was applied, and (ANOVA) was calculated for the degrees of the sample individuals in knowledge of food labels, and the following tables show that:

Table 1. Differences in the mean degrees of knowledge of food labels among the sample individuals according to the gender variable.

Gender	Mean	Std. Deviation	N	df	t	Sig
Men	29.546	2.571	591	996	2.334	0.05
Women	27.136	2.013	407			

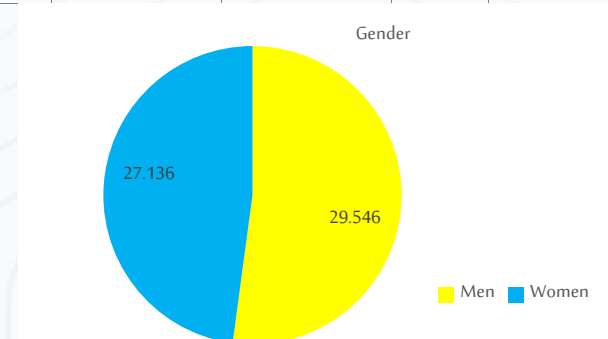


Figure 1. Differences in the mean degrees of the sample individuals in their knowledge of food labels according to the gender variable.

From Table (1) and Figure (1), it is clear that the value of (t) was (2.334), and it is statistically significant at the level (0.05) in favor of men, where the mean of men's degree reached (29.546), while the mean of women's degree reached (27.136). This indicates that men were more aware of food labels than women.

Table 2. Differences in the mean of degrees of the sample individuals in their knowledge of food labels according to the nationality variable.

Nationality	Mean	Std. Deviation	N	df	t	Sig
Saudi	31.478	3.159	563	996	7.269	0.01
Non-Saudi	24.006	2.316	435			

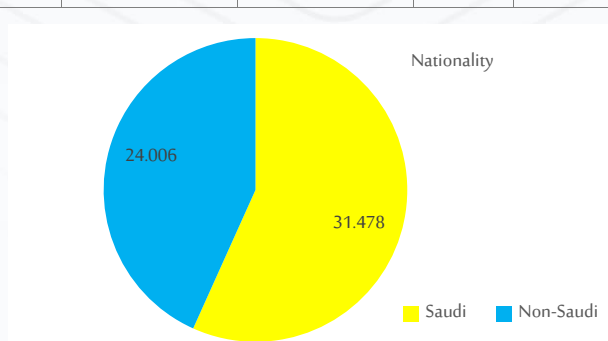


Figure 2. Differences in the mean degrees of the sample individuals in the knowledge of food labels, according to the nationality variable.

From Table (2) and Figure (2), it is clear that: the value of (t) was (7.269), and it is statistically significant at the level (0.01) in favor of Saudi, where the mean of Saudi's degree reached (31.478), while the mean of non-Saudi's degree reached (24.006). This indicates that Saudis were more aware of food labels than non-Saudis.

Table 3. Analysis of variance for the degrees of knowledge of food labels according to the marital status variable.

Marital status	Sum of Squares	Mean Square	df	F	Sig
Between Groups	0.125	0.063	2	1.963	0.141
Within Groups	31.710	0.032	995		Not significant
Total	31.835		997		

It is clear from Table (3) that the value of (F) was (1.963), and it is not a statistically significant value, which indicates that there are no existing differences among the degrees of knowledge of food labels according to the marital status variable.

Table 4. Analysis of variance for the degrees of knowledge of food labels according to the education variable.

Education	Sum of Squares	Mean Square	df	F	Sig
Between Groups	78140.946	39070.473	2	47.345	0.01
Within Groups	821094.515	825.221	995		
Total	899235.461		997		

It is clear from Table (4) that the value of (F) was (47.345), and it is a statistically significant value at the level of (0.01), which indicates that there are differences among the degrees of the sample individuals in the knowledge of food labels according to the education variable, and to know the direction of the significance, a Scheffe's test for the multiple comparisons was applied, and the following table shows the results obtained from this analysis:

Table 5. Scheffe's test for the multiple comparisons.

Education	High School or Diploma M = 15.053	Bachelor M = 20.156	Masters / PhD M = 28.111
High School or Diploma	-		
Bachelor	5.103**	-	
Masters / PhD	13.058**	7.955**	-

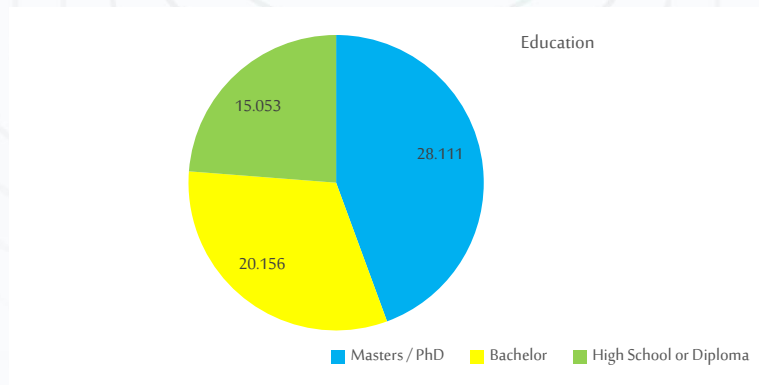


Figure 3. Differences in degrees of knowledge of food labels according to the education variable.

From Table (5) and Figure (3), it is clear that there are differences in knowledge of food labels among the sample individuals who have masters / Ph.D. and both of the sample individuals who have bachelor and the sample individuals who have high school or diplomain favor of the sample individuals who have Masters / Ph.D. at the significance level of (0.01). Also, there are differences among the sample individuals who have bachelor and the sample individuals who

have high school or diploma in favor of the sample individuals who have bachelor at the significance level of (0.01), where the mean degree of the sample individuals who have masters / Ph.D. reached (28.111), followed by the sample individuals who have bachelor by mean of (20.156), followed by the sample individuals who have High school or diploma by mean of (15.053). So, the sample individuals who have masters / PhD come in the first rank, where they were more aware of the knowledge of food labels, then the sample individuals who have bachelor, then the sample individuals who have high school or diploma in the last rank.

Table 6. Analysis of variance for the degrees of knowledge of food labels according to the age variable.

Age	Sum of Squares	Mean Square	df	F	Sig
Between Groups	79007.984	39503.992	2	52.272	0.01
Within Groups	751966.391	755.745	995		
Total	830974.375		997		

It is clear from Table (6) that: the value of (F) was (52.272), and it is a statistically significant value at the level of (0.01), which indicates that there are differences among the degrees of the sample individuals in the knowledge of food labels according to the age variable, and to know the direction of the significance, a Scheffe's test for the multiple comparisons was applied, and the following table shows this:

Table 7. Scheffe's test for the multiple comparisons.

Age	Less than 35 years M = 13.425	From 35 to 45 years M = 22.387	From 46 years or more M = 31.559
Less than 35 years	-		
From 35 to 45 years	8.962**	-	
From 46 years or more	18.134**	9.172**	-

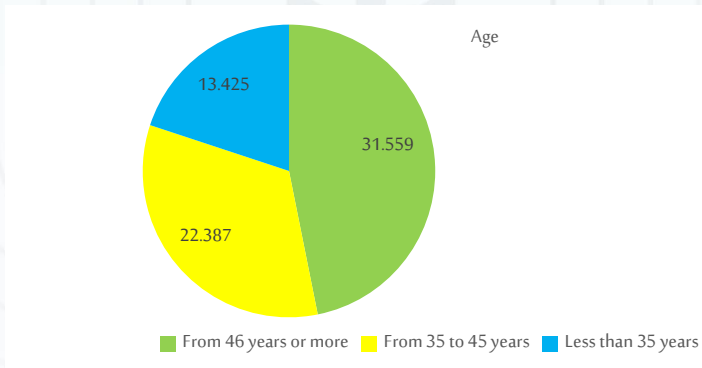


Figure 4. Differences in degrees of knowledge of food labels according to the age variable.

From Table (7) and Figure (4), it is clear that there are differences in the knowledge of food labels among the sample individuals whose ages range from 46 years or more, and both the sample individuals whose ages range from 35 to 45 years (less than 35 years) are in favor of the sample individuals whose ages range from 46 years or more at the significance level of (0.01). Also, there are differences between the sample individuals' ages from 35 to 45 years old and the sample individuals ages less than 35 years old in favor of the sample individuals aged from 35 to 45 years at the significance level of (0.01), where the mean degree of the sample individuals whose age is 46 years or more reached (31.559), followed by the sample individuals whose age is from 35 to 45 years by a mean of (22.387), followed by the sample individuals whose age are less than 35 years by a mean of (13.425). The result shows that the sample individuals

whose age is 46 years or more come in the first rank, where they are more aware of the knowledge of food labels; then, the sample individuals whose age is 35 to 45 years come in the second rank; and in the last rank, the sample individuals whose age is less than 35 years.

Table 8. Differences in the mean degrees of knowledge of food labels according to the employment variable.

Employment	Mean	Std. Deviation	N	df	t	Sig
Employed	26.424	2.137	686	996	15.801	0.01
Unemployed	12.331	1.248	312			

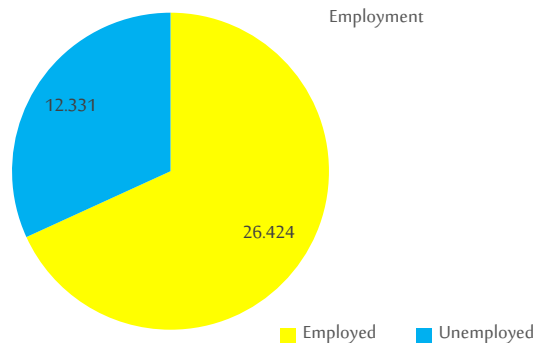


Figure 5. Differences in the mean degrees of the sample individual's knowledge of food labels according to the employment variable.

From Table (8) and Figure (5), it is clear that the value of (t) was (15.801), and it is statistically significant at the level (0.01) in favor of employed, where the mean degree of employed reached (26.424), while the mean degree of unemployed reached (12.331). This indicates that participants who were employed were more aware of food labels than the unemployed.

Table 9. Analysis of variance for the degrees of knowledge of food labels according to the monthly income variable.

Monthly income (Saudi Riyal)	Sum of Squares	Mean Square	df	F	Sig
Between Groups	75583.703	37791.852	2	35.877	0.01
Within Groups	1048109.590	1053.376	995		
Total	1123693.293		997		

It is clear from Table (9) that the value of (F) was (35.877), and it is a statistically significant value at the level of (0.01), which indicates that there are differences among the degrees of knowledge of food labels according to the monthly income variable. To know the direction of the significance, Scheffe's test for the multiple comparisons was applied, and the following table shows this:

Table 10. Scheffe's test for the multiple comparisons.

Monthly income Saudi Riyal)	Less than 5000 M = 14.003	From 5000 to 10000 M = 16.518	Over 10000 M = 27.991
Less than 5000	-		
From 5000 to 10000	2.515*	-	
Over 10000	13.988**	11.473**	-

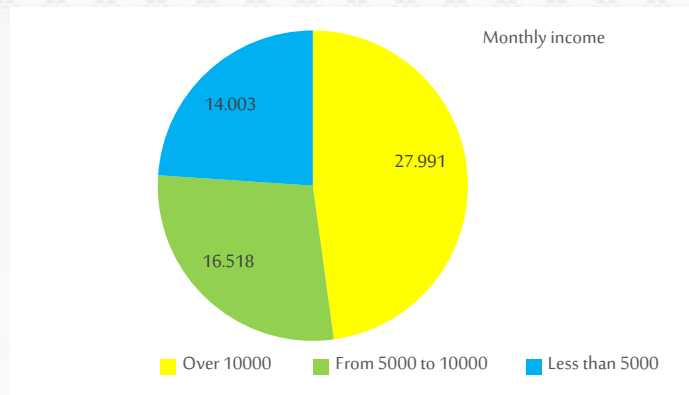


Figure 6. Differences in degrees of knowledge of food labels among the sample individuals according to the monthly income variable.

From Table (10) and Figure (6), it is clear that there are differences in knowledge of food labels among the sample individuals whose income is over 10000 and both the sample individuals whose income is (from 5000 to 10000 . less than 5000) in favor of the sample individuals whose income is over 10000 at the significance level of (0.01). There are differences among the sample individuals whose income is from 5000 to 10000 and the sample individuals whose income is less than 5000 in favor of the sample individuals whose income is from 5000 to 10000 at the significance level of (0.05), where the mean degree of the sample individuals whose income is over 10000 reached (27.991), followed by the sample individuals whose income is from 5000 to 10000 by mean of (16.518), and finally, the sample individuals whose income is less than 5000 by mean of (14.003). Therefore, the sample individuals whose income is over 10000 come in the first rank, where they are more aware of the knowledge of food labels; then, the sample individuals whose income is from 5000 to 10000 come in the second rank; and in the last rank, the sample individuals whose income is less than 5000.

**The second hypothesis:**

There is a correlation relation between the knowledge of food labels and the variables of the study.

To verify the validity of this hypothesis, a correlation matrix was created between the knowledge of food labels and the variables of the study, and the following table shows the values of the correlation coefficients:

Table 11. The correlation matrix between knowledge of food labels and the variables of the study.

Variables	Knowledge of food labels
Gender	0.263
Nationality	0.158
Marital status	0.201
Education	0.948**
Age	0.651*
Employment	0.876**
Monthly income	0.793**

\*\* significant at 0.01      \* significant at 0.05      without stars not significant

From Table (11) it is clear that there is a direct correlation between the knowledge of food labels and some of the study variables at the significance level of 0.01, and 0.05. Therefore, an increase in the level of education has a concomitant increase in the awareness of food labels. Furthermore, an increase in age was correlated with an increase in, the

awareness of knowledge of food labels. Additionally, an increase in the number of people who are in employment increased the awareness of knowledge of food labels. A similar increase in the awareness of the knowledge of food labels was observed with an increase in the monthly. On the contrary, there is no correlation between gender, nationality and marital status and the awareness of the knowledge of food labels.

**The third hypothesis:**

The participation percentage of the factors affecting the knowledge of food labels varies.

To verify this hypothesis, the relative importance was calculated using the regression coefficient (the graded step to forward) for the factors affecting the knowledge of food labels, and the following table shows that:

Table 12. The relative importance of using the regression coefficient (regression stepwise) of the factors affecting the knowledge of food labels.

Dependent variable knowledge of food labels	Independent variable	R	R Square	F	Sig	Beta	t	Sig
	Education	0.918	0.843	150.543	0.01	0.701	12.275	0.01
	Age	0.861	0.742	80.611	0.01	0.569	8.974	0.01
	Employment	0.817	0.667	56.145	0.01	0.481	7.493	0.01
	Gender	0.795	0.631	47.945	0.01	0.440	6.924	0.01

From the previous table, Table 12 it is clear that education was one of the most influential factors in the knowledge of food labels at 84.3%, followed by age at 74.2%, followed by employment at 66.7%, and gender at 63.1% in the last rank the gender by 63.1%.

**4. Conclusions**

This study aimed to assess pilgrims' knowledge of nutritional labeling information on food during Hajj. Our results show that the majority of the total participants were Saudi men. The sample individuals who have a master's or Ph.D. come in the first rank, The data show that the sample individuals aged 46 years or more were more aware of the knowledge of food labels. The results indicate that the employed were more aware of food labels than the unemployed. The results show that, if the monthly income gets higher, the awareness of the knowledge of food labels increases, while there is no correlation between nationality and marital status and awareness of food labels. From the results, it is clear that education was one of the most influential factors in the knowledge of food labels

**5. Recommendations**

Based on the findings of this study, the following recommendations are made:

- There is a need to increase the spreading awareness of the importance of reading nutritional labeling information about foods for Pilgrims to help them choose their correct food to reduce the risk factors that can be linked to the occurrence of some diet related diseases.
- Spreading awareness could be initiated before pilgrimage to Saudi Arabia and during the Hajj period by publishing brochures, giving educational lectures, teaching them how to read the labels, and providing small and easy-to-carry devices in many places to read the labels in several languages for those who are unable to read.
- All food that is supplied to Pilgrims should be labeled, especially for people who have chronic disease.

## References

1. Al-Mughthem, A., Jradi, H. and Bawazir, A. (2020). Nutrition food labeling in the Saudi market between compliance and relaxing policy. *Asian Journal of Medicine and Health* pp. 1–8. doi:10.9734/ajmah/2020/v18i530200.
2. Ahmed , O.B. et al. (2019) 'Nutrition and Chronic Diseases among Makkah Visitors ', *Global Journal of Medical Research*, 19(1), pp. 31–36. doi:https://globaljournals.org/GJMR\_Volume19/5-Nutrition-and-Chronic-Diseases.pdf.
3. Allergen labelling for consumers Standards Australia New Zealand. Available at: <https://www.foodstandards.gov.au/consumer/labelling/allergen-labelling>. (Accessed: October 14, 2023).
4. Labelling information for consumers- Food Standards Australia New Zealand - Available at: <https://www.foodstandards.gov.au/consumer/labelling/pages/default.aspx> (Accessed: 10 October 2023).
5. Food labelling | National Health Service inform. Available at: [https://www.nhsinform.scot/healthy-living/food-and-nutrition/food-packaging/food-labelling#:~:text=Nutrition%20labels%20must%20display%20the,100%20ml\)%20of%20the%20food](https://www.nhsinform.scot/healthy-living/food-and-nutrition/food-packaging/food-labelling#:~:text=Nutrition%20labels%20must%20display%20the,100%20ml)%20of%20the%20food). (Accessed: 09 October 2023).
6. Food labeling, Food and Agriculture Organization of the United Nations. Available at: <https://www.fao.org/food-labelling/en/> (Accessed: 09 October 2023).
7. Hajj statistics publication, General Authority for Statistics. Available at: <https://www.stats.gov.sa/en/28> (Accessed: 09 October 2023).
8. Saidovna, V.F. (2021) 'The Functional Essence of Some Pilgrimage Terms in The English Language', *Eurasian Research & Bulletin*, 3, pp. 1–6.
9. Jáuregui, A. et al. (2020) 'Impact of front-of-pack nutrition labels on Consumer Purchasing Intentions: A randomized experiment in low- and middle-income Mexican adults', *BMC Public Health*, 20(1). doi:10.1186/s12889-020-08549-0.
10. Saudi Ministry of Health. Covid-19 guidelines, Available at: <https://www.moh.gov.sa/en/AwarenessPlatform/HealthyLifestyle/Pages/default.aspx> (Accessed: October 14, 2023).
11. Saudi food and drug Authority. Food labeling, Available at: <https://www.sfda.gov.sa/ar/awarenesscampaign/74362> (Accessed: October 22, 2023).
12. Turkistani, A.M. (2022) 'The special dietary needs of pilgrims and practices of agencies regarding food quality and safety during the Hajj', *Biosciences Biotechnology Research Asia*, 19(3), pp. 757–766. doi:10.13005/bbra/3028.



## A Survey of Using a Novel Mathematical Model (SEIRQ, SEIR) of COVID-19 Epidemic: On Analyze the Spread of Epidemics and Infectious Diseases in Saudi Arabia

Najat A. Alghamdi

Mathematics Department, College of Science, Umm Al-Qura University

\*Corresponding author: E-mail (naghamdi@uqu.edu.sa)

### دراسة استقصائية لاستخدام نموذج رياضي جديد لوباء كوفيد - 19 حول تحليل انتشار الأوبئة والأمراض المعدية في المملكة العربية السعودية

نجاة عتيق الغامدي

قسم الرياضيات - كلية العلوم، جامعة أم القرى

#### الملخص

من أجل السيطرة على انتشار الأمراض المعدية (كوفيد-19) والأوبئة، فإنه من المهم جدا ان يكون القائمون على الأمر متقدمين على الوضع بخطوة حتى يتم الحد من انتشار الأمراض. ومن أجل القيام بذلك، يمكن بناء نماذج رياضية من بيانات مدروسة ومختبرة جيدا، وطبعا اعتمادا على بيانات حقيقة عن انتشار المرض مثل عدد الأفراد قيد الدراسة، معدلات الإصابة، معدلات الشفاء، معدلات الوفاة وهكذا. ثم بعد ذلك نقوم بتحديد النموذج الأقرب للوضع على أرض الواقع واختباره مقابل بيانات محددة لمرض معين يؤكد مصداقيته من خلال مقارنته بالوضع على أرض الواقع. وبعد التأكد من صحة النموذج نقوم بالتنبؤ بمدى انتشار المرض في المستقبل. يتم اعتماد استخدام هذا النموذج لمحاكاة انتشار هذا المرض إذا كان التنبؤ المبني على هذا النموذج قريب جداً من القراءات التي تم رصدها. ويمكن استخدام هذا النموذج لتحديد المعدلات والأسباب التي قد تساعد في السيطرة على هذا المرض وكسر موجة انتشاره، وإطلاق بروتوكول للسيطرة على انتشار الوباء وعلاجه.

#### Abstract

In order to control the spread of infectious diseases (such as COVID-19) and epidemics, authorities must remain one step ahead of the situation until the spread is curtailed. To do this, mathematical models can be constructed from well-studied and tested data, such as the number of individuals under study, infection rates, recovery rates, death rates, and so forth. Testing the model against specific data for a specific disease confirms its credibility by comparing it to the situation on the ground. After ensuring the validity of the model, we predict the spread of the disease in the future. Using this model to simulate the spread of this disease is adopted if the prediction based on this model is very close to the readings that were monitored. This model can be used to determine the rates and causes that may help control this disease break the wave of its spread, and launch a protocol to control the spread of the epidemic and treat it.



**Keywords:** COVID-19; Epidemics; Infectious Diseases; Reproduction number; SEIQR model; SEIR model

## 1. Introduction

Mathematical models for disease are effective for understanding the dynamical evolution and transmission of infectious diseases and help us to take the necessary measures to enter health and thus control the disease. In early 2019, the people of Wuhan, and China suffered an unknown infection from pneumonia [1, 2]. The cause of this pneumonia is a new coronavirus called 2019-nCoV, or SARS-CoV-2, and it is named COVID-19. In 2003, SARS (severe acute respiratory syndrome) broke out in China [3-5], in 2012 it spread to Saudi Arabia as Middle East Respiratory Syndrome (MERS) [6, 7], and in 2015 it spread to Korea as MERS [8]. The United States of America is one of the most common outbreaks of the disease after China. Symptoms of COVID-19 are similar to SARS and MERS infections.

COVID-19 has become one of the great challenges in the world, and this came as a result of its rapid spread and danger to human health, as it caused many deaths all over the world [9-15]. Since the Coronavirus is transmitted from person to person with unknown dynamics to this day, it is difficult to take appropriate measures or strategies to protect the spread of COVID-19, so it will be an epidemic in Saudi Arabia and cause the death of many Saudis and residents.

Medical and biological research and mathematical modeling play a crucial role in stopping COVID-19, whether by discovering drugs or medical vaccines or even studying the dynamics of the disease to stop its spread as in mathematical modeling [16-20]. Through mathematical modeling, we can expect the point of injury and the time of injury and thus appropriate procedures and strategies to prevent the spread of COVID-19 and all epidemics. Also, mathematical modeling through dynamic equations can describe the dynamic characteristics of epidemics [19, 20]. In 2019, the COVID-19 virus spread rapidly around the world, becoming a global pandemic.

Whereas, much research has been done on COVID-19 related to statistical methodology or mathematical modeling for gives us epidemiological data in the world to increase social awareness and thus define precautionary strategies and measures [19]. Wu et al. [9] have proposed a structure for the SEIR model to predict disease outbreaks globally based on tracking data from December 31, 2019, to January 28, 2020. Read et al. [10] provided a way to spread the disease from month to month in the Chinese city of Wuhan. Imai et al. [11] studied the SIR model to restrict the increased prevalence of COVID-19 by applying quarantine measures. In this work, we have developed an epidemiological SEIQR, SEIR model for studying COVID-19 in Saudi Arabia by using mathematical modeling. In this model, we divided the population into five or four sub-populations (or five or four cells), and by using mathematical modeling through dynamic equations we described the dynamic characteristics of COVID-19 and all epidemics.

## 2. Methodology

As the fight against infectious diseases and the spread of epidemics and viruses continues, those in charge of the matter must remain one step ahead of the problem until the spread is curbed and the situation is controlled. In mathematical modeling, this can be achieved by building well-studied and tested mathematical models that simulate reality, of course, based on real data such as the number of people under study, infection rates, recovery rates, and death rates. Afterward, we determine the closest model to the ground situation, and then we test it with specific disease data to confirm its credibility. Our next step is to predict the spread of this disease in the future to verify its validity. If the prediction based on this model is very close to the readings monitored, then the model is adopted as a model to simulate the spread of the disease in the future. As a result of studying this model, it is possible to determine what are the rates and causes that can be used to control the outbreak as well as devise a treatment protocol to control its spread.

### Formulation of A Novel Coronavirus Disease (SEIRQ Model or SEIR):

During the spreading of COVID-19 in any country, the population could be divided into five dynamic sub-populations or five cells which are described as follows:

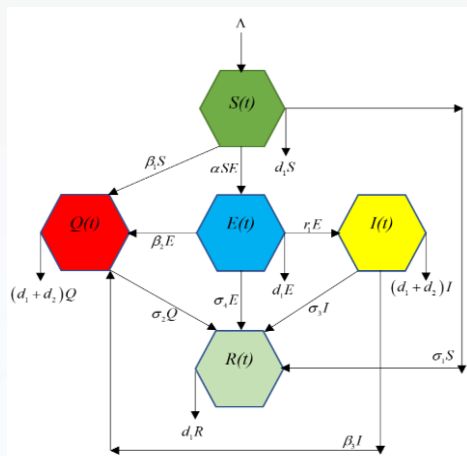


Figure (1-a): The flowchart of the SEIRQ model

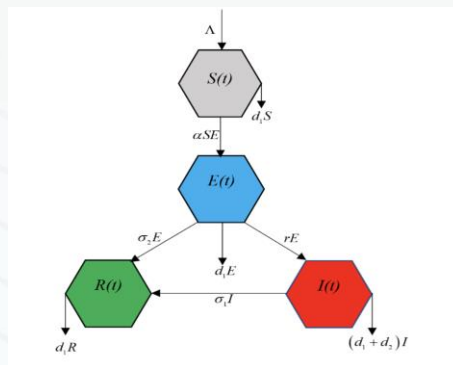


Figure (1-b): The flowchart of the SEIR model

### 3. Results and Discussion

#### For SEIRQ model:

The total population size is, which is defined as [1, 7, 20]:

$$N(t) = S(t) + E(t) + I(t) + R(t) + Q(t). \quad (1)$$

The following system of first-order ordinary non-linear differential equations [1, 7, 20]:

$$\frac{dS(t)}{dt} = \Lambda - \alpha S(t)E(t) - \beta_1 S(t) - \sigma_1 S(t) - d_1 S(t), \quad (2)$$

$$\frac{dE(t)}{dt} = \alpha S(t)E(t) - r_1 E(t) - \beta_2 E(t) - d_1 E(t) - \sigma_2 E(t), \quad (3)$$

$$\frac{dI(t)}{dt} = r_1 E(t) - \beta_3 I(t) - \sigma_3 I(t) - d_1 I(t) - d_2 I(t), \quad (4)$$

$$\frac{dR(t)}{dt} = \sigma_1 S(t) + \sigma_2 Q(t) + \sigma_3 I(t) + \sigma_4 E(t) - d_1 R(t), \quad (5)$$

$$\frac{dQ(t)}{dt} = \beta_1 S(t) + \beta_2 E(t) + \beta_3 I(t) - \sigma_2 Q(t) - d_1 Q(t) - d_2 Q(t). \quad (6)$$

#### Theorem 1 (All solutions are definite positive):

Each solution of the SEIRQ model with its initial condition is a subset in the interval and  $\{S(t), E(t), I(t), R(t), Q(t)\} \geq 0$  for all values  $0 \leq t < \infty$ .

#### Theorem 2 (Domain of solutions)

All the solutions of the model structure that initiate  $\mathbb{R}_+^5$  are bounded inside the region defined by

$$\psi = \left\{ (S, E, I, R, Q) \in \mathbb{R}^5 : 0 \leq N(t) \leq \frac{\Lambda}{d_1} \right\}.$$

#### The equilibrium of the SEIRQ model

To determine the equilibrium of this model, we set all the derivatives equal to zero and solve the system which gives [7]:

$$S(t) = \frac{\varepsilon_2}{\alpha}, \quad E(t) = \frac{\varepsilon_1}{r_1} I(t), \quad I(t) = \frac{r_1 \varepsilon_1}{\delta \alpha} \left( \frac{\alpha \Lambda}{\varepsilon_1 \varepsilon_2} - 1 \right) = \frac{r_1 \varepsilon_1}{\delta \alpha} (\mathfrak{R}_0 - 1), \quad (7)$$

where  $\mathfrak{R}_0 = \frac{\alpha \Lambda}{\varepsilon_1 \varepsilon_2 (\beta_1 + \sigma_1 + d_1)(r_1 + \beta_2 + d_1 + \sigma_2)}$

The number  $\mathfrak{R}_0$  is called the reproduction number (RBN) [1, 7].

**Theorem 3 (Stability analysis of disease-free equilibrium)**

$$\mathfrak{R}_0 = \begin{cases} \mathfrak{R}_0 < 1 & \text{Stable} \\ \mathfrak{R}_0 = 1 & \text{Unstable} \\ \mathfrak{R}_0 > 1 & \text{Unstable} \end{cases} \quad (8)$$

**Theorem 4 (Global stability of equilibria of the SEIR model)**

The SEIRQ model  $DFE(E_0) = \left( \frac{\Lambda}{\varepsilon_1}, 0, 0, 0, 0 \right)$  is globally stable of the disease-free equilibrium under the condition

$$\mathfrak{R}_0 < 1.$$

**Numerical Verification and Predictions**

The specific evidence for the COVID-19 epidemic in Saudi Arabia was tested. By 3 March 2020, COVID-19 had spread to Saudi Arabia. A few COVID-19 cases were identified until 1 April 2020 after which the number of cases was reported to increase. Therefore, we considered 1 April 2020 as the real start of the COVID-19 epidemic in Saudi Arabia. We used tables of statistics issued by the Saudi Ministry of Health to obtain more information about the population, mortality rate, and population growth rate in Saudi Arabia. We also assessed the daily official statement issued by the Saudi Ministry of Health, as well as Wikipedia™<sup>27</sup> (which also uses data from the Saudi Ministry of Health). To study the spread of COVID-19 in Saudi Arabia up to 5 August 2020, we represented the curve of the number of (daily and total) infections in Saudi Arabia between 4/1/2020 and 6/10/2020, as shown in Figs. 2 and 3, respectively. Also, we represented the curve of the number of (daily and total) infections based on the SEIRQ model with various values of parameters against the real data in KSA between 4/1/2020 and 6/10/2020, as shown in Figs. 4 and 5, respectively. In Figure 6, we predicted the total number of infections based on the SEIRQ model with various values of parameters in KSA for 300 days between 4/1/2020 and 1/24/2021. Figs. 7, 8, and 9, show the ideal protocol to break down spreading COVID-19 in Saudi Arabia [21-23].

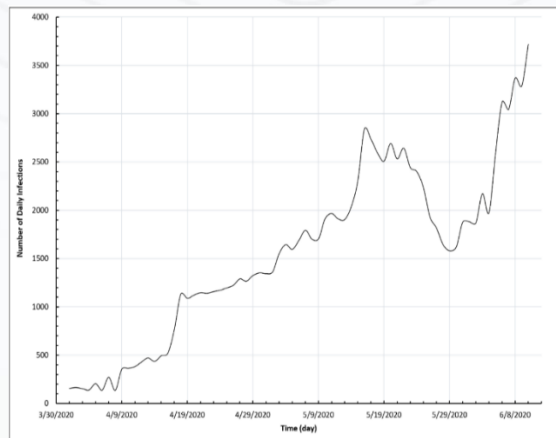


Figure 2: The number of daily infections in Saudi Arabia between 4/1/2020 and 6/10/2020

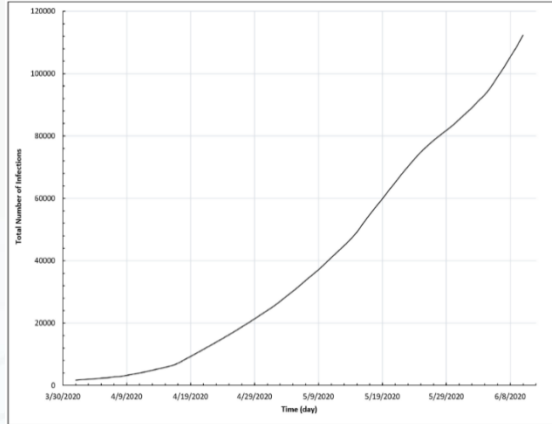


Figure 3: The total number of infections in KSA between 4/1/2020 and 6/10/2020

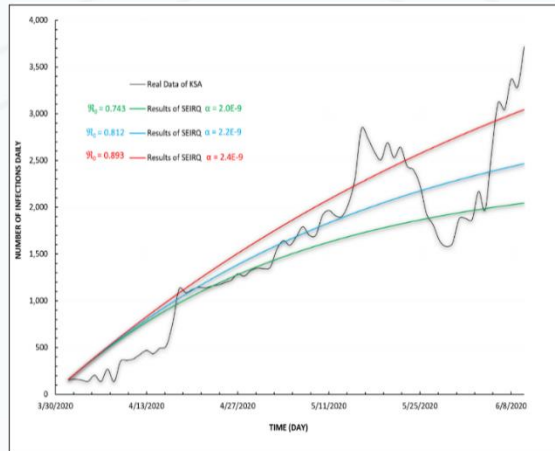


Figure 4: The number of daily infections based on the SEIRQ model with various values of parameters against the real data in KSA between 4/1/2020 and 6/10/2020

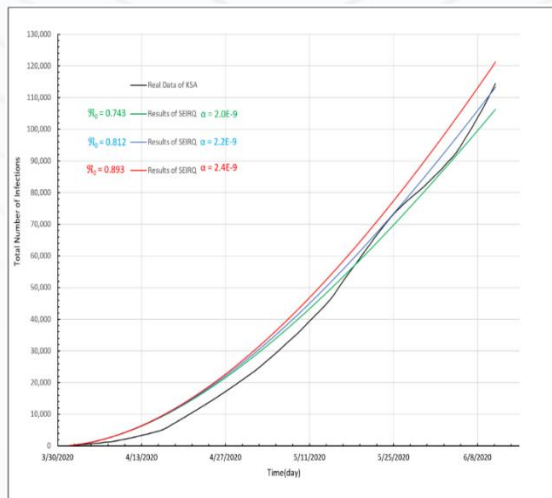


Figure 5: The number of total infections based on the SEIRQ model with various values of parameters against the real data in KSA between 4/1/2020 and 6/10/2020.

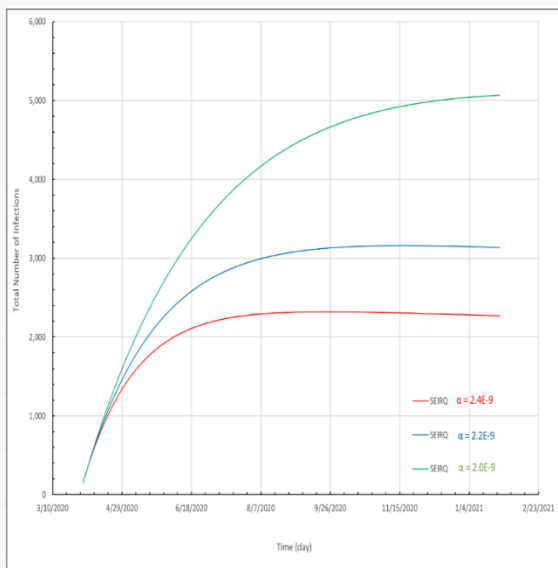
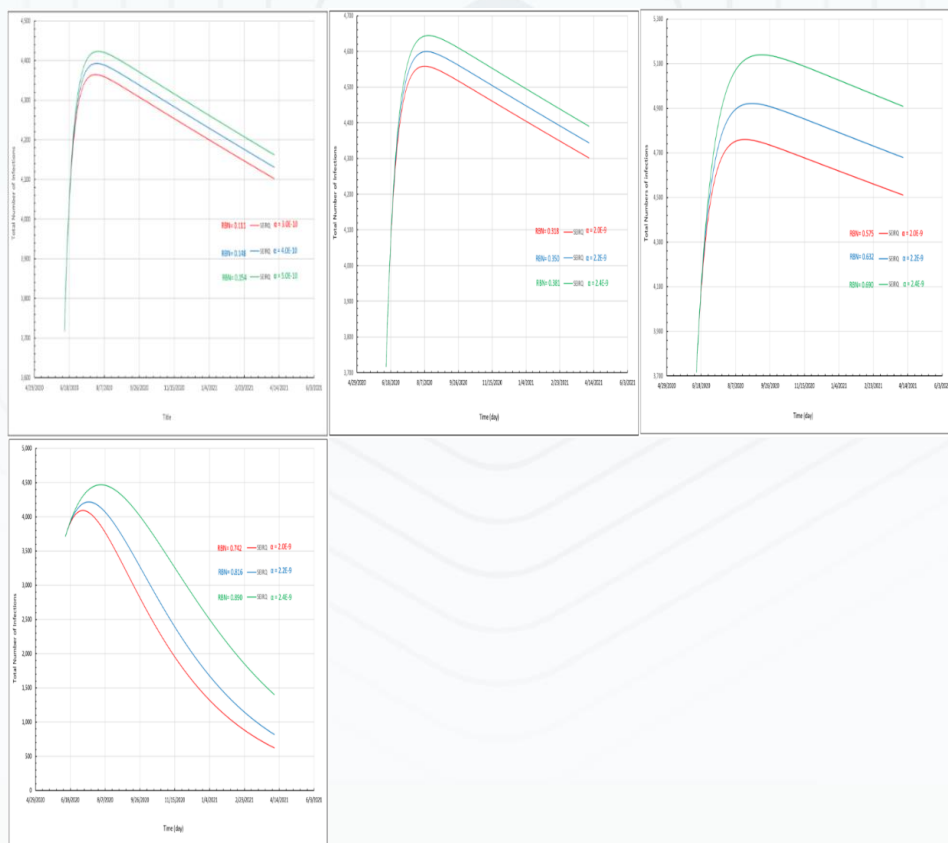
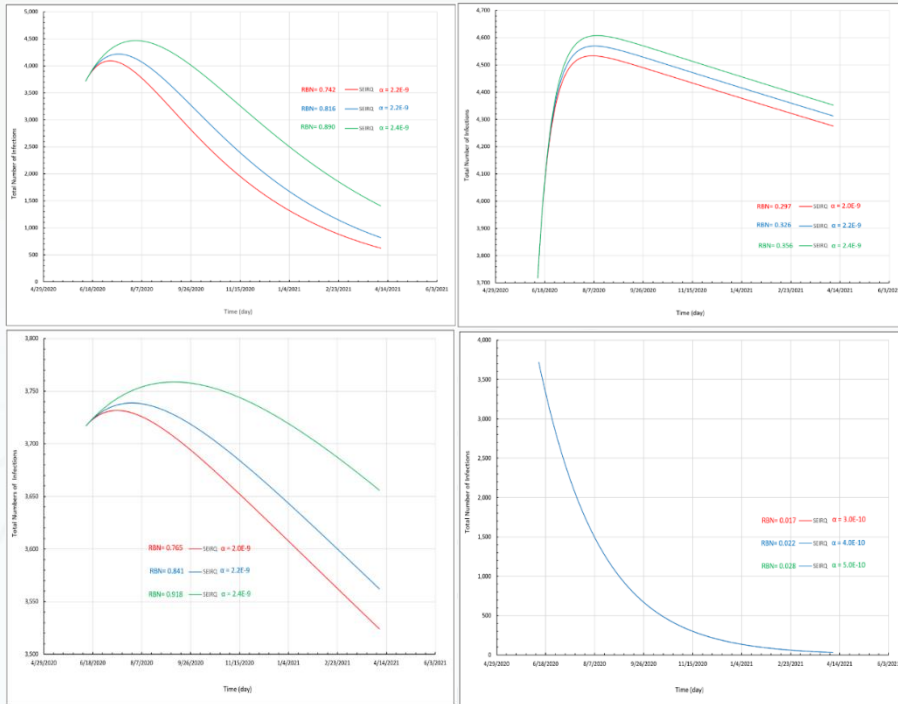


Figure 6: The total number of infections based on the SEIRQ model with various values of parameters in KSA for 300 days between 4/1/2020 and 1/24/2021.



Figures 7: The ideal protocol to break down spreading COVID-19 in Saudi Arabia



Figures 8: The ideal protocol to break down spreading COVID-19 in Saudi Arabia

### The ideal protocol to break down the spreading of COVID-19 in Saudi Arabia:

To get the ideal situation that can help us to break down the spreading of COVID-19 in Saudi Arabia, we must start applying the following protocol and procedures (see Figures 7, 8, 9):

1. They are decreasing the value of the transmission rate from the susceptible population to the infected but not detected by testing the population to be in the following interval  $\alpha = [3.0 - 5.0] \times 10^{-10}$ .
2. They are increasing the value of the transmission coefficient from a susceptible population to a quarantine population  $\beta_1$  to be  $\beta_1 \geq 1.0 \times 10^{-4}$ . We do not mean by the quarantine an isolated place; we say stay away and stay at home as much as possible.
3. They are increasing the value of the transmission coefficient from infected but not detected by testing population to quarantine population  $\beta_2$  to be  $\beta_2 \geq 1.3$ , which means expanding the work of the test of detecting and the need to isolate infected people in isolated areas such as compulsory quarantine.
4. They are increasing the transmission rate from the infected population to the secured zone population, which means that we must translate the infected people to an isolated area such as compulsory quarantine, or prevent them from moving around with a non-infected population.
5. They are increasing the value of the transmission coefficient from a susceptible population to a secured zone population to a recovery population. This means that we protect the majority population from the spreading of COVID-19 by using supplements and vaccines that help strengthen the immune system and work with the principle that prevention is better than treatment.

6. They are increasing the value of the transmission rate from infected and detected by testing the population to recovery by using a successful treatment.
7. They are increasing the value of the transmission rate from infected and not detected by testing the population to recovery by using a successful treatment.
8. They are decreasing the value of infected but not detected by testing population to infected population for treatment to be, which means we have to offer the treatment for suspected cases before exacerbation of infection and the appearance of symptoms and improved health.

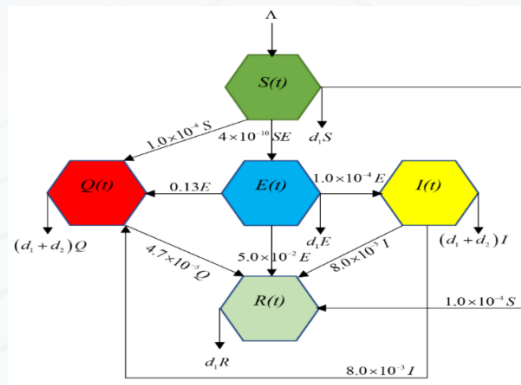


Figure 9: Protocol and procedures to break down the spreading of COVID-19 in Saudi Arabia

## Conclusion

- We can predict infection spread through this project.
- Models can be used to estimate infections based on observed data that are generated by the model.
- Also, this project can contribute to the development of a treatment protocol aimed at controlling the epidemic's spread.
- The mathematical model for the project further enables the prediction of the time and reasons for the breakdown of the wave of epidemic spread so that the epidemic can be controlled.
- As infectious diseases and epidemics are developing every day and do not end, this project can be maintained since the added value of this project will remain important with occasional updates to keep pace with new and mutated diseases and epidemics.

## Acknowledgment

This work is a survey of a research project submitted to the Research and Development Grants Program for National Research Institutions and Centers (GRANTS), Target Research Program, Infectious Diseases Research Grant Program, King Abdulaziz City for Science and Technology (KACST), Kingdom of Saudi Arabia, to fund this project and this work. The author is very grateful and thanks the corresponding author: Prof. Hamdi Youssef and all the work team.

## References:

1. M.A. Khan, A. Atangana, Modeling the dynamics of novel coronavirus (2019-nCov) with fractional derivative, Alexandria Engineering Journal 59(4) (2020) 2379-2389.
2. H. Lu, C.W. Stratton, Y.W. Tang, Outbreak of pneumonia of unknown etiology in Wuhan, China: The mystery and the miracle, Journal of medical virology 92(4) (2020) 401.

3. M. Goyal, H.M. Baskonus, A. Prakash, An efficient technique for a time fractional model of lassa hemorrhagic fever spreading in pregnant women, *The European Physical Journal Plus* 134(10) (2019) 482.
4. W. Gao, P. Veeresha, D. Prakasha, H.M. Baskonus, G. Yel, New approach for the model describing the deadly disease in pregnant women using Mittag-Leffler function, *Chaos, Solitons & Fractals* 134 (2020) 109696.
5. D. Kumar, J. Singh, M. Al Qurashi, D. Baleanu, A new fractional SIRS-SI malaria disease model with application of vaccines, antimalarial drugs, and spraying, *Advances in Difference Equations* 2019(1) (2019) 1-19.
6. K. Shah, M.A. Alqudah, F. Jarad, T. Abdeljawad, Semi-analytical study of Pine Wilt Disease model with convex rate under Caputo–Febrizio fractional order derivative, *Chaos, Solitons & Fractals* 135 (2020) 109754.
7. M. Martcheva, *An introduction to mathematical epidemiology*, Springer 2015.
8. P. Van den Driessche, J. Watmough, Reproduction numbers and sub-threshold endemic equilibria for compartmental models of disease transmission, *Mathematical biosciences* 180(1-2) (2002) 29-48.
9. J.T. Wu, K. Leung, G.M. Leung, Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling study, *The lancet* 395(10225) (2020) 689-697.
10. J.M. Read, J.R. Bridgen, D.A. Cummings, A. Ho, C.P. Jewell, Novel coronavirus 2019-nCoV: early estimation of epidemiological parameters and epidemic predictions (preprint). (2020) ,
11. N. Imai, A. Cori, I. Dorigatti, M. Baguelin, C. Donnelly, S. Riley, N. Ferguson, Report 3: transmissibility of 2019-nCoV. (2020) ,
12. B. Tang, X. Wang, Q. Li, N.L. Bragazzi, S. Tang, Y. Xiao, J. Wu, Estimation of the transmission risk of the 2019-nCoV and its implication for public health interventions, *Journal of clinical medicine* 9(2) (2020) 462.
13. Q. Guo, M. Li, C. Wang, P. Wang, Z. Fang, J. Tan, S. Wu, Y. Xiao, H. Zhu, Host and infectivity prediction of Wuhan 2019 novel coronavirus using deep learning algorithm, *BioRxiv* (2020) 2020.01. 21.914044.
14. C. Yang, J. Wang, A mathematical model for the novel coronavirus epidemic in Wuhan, China, *Mathematical biosciences and engineering: MBE* 17(3) (2020) 2708.
15. K. Wang, Z. Lu, X. Wang, H. Li, H. Li, D. Lin, Y. Cai, X. Feng, Y. Song, Z. Feng, Current trends and future prediction of novel coronavirus disease (COVID-19) epidemic in China: a dynamical modeling analysis, *Mathematical biosciences and engineering* 17(4) (2020) 3052-3061.
16. R. Ud Din, K. Shah, I. Ahmad, T. Abdeljawad, Study of transmission dynamics of novel COVID-19 by using mathematical model, *Advances in Difference Equations* 2020 (2020) 1-13.
17. L. Peng, W. Yang, D. Zhang, C. Zhuge, L. Hong, Epidemic analysis of COVID-19 in China by dynamical modeling, *arXiv preprint arXiv:2002.06563*. (2020)
18. J.F. Rabajante, Insights from early mathematical models of 2019-nCoV acute respiratory disease (COVID-19) dynamics, *arXiv preprint arXiv:2002.05296*. (2020)
19. L. Mangoni, M. Pistilli, Epidemic analysis of Covid-19 in Italy by dynamical modelling, Available at SSRN 3567770. (2020)
20. [20]S.S. Nadim, I. Ghosh, J. Chattopadhyay, Short-term predictions and prevention strategies for COVID-19: a model-based study, *Applied mathematics and computation* 404 (2021) 126251.
21. Public Health Authority <https://covid19.cdc.gov.sa>, 2020
22. Saudi Ministry of Health, <https://www.moh.gov.sa>, 2020.
23. COVID-19 in Saudi Arabia, [https://en.wikipedia.org/wiki/COVID-19\\_pandemic\\_in\\_Saudi\\_Arabia](https://en.wikipedia.org/wiki/COVID-19_pandemic_in_Saudi_Arabia), 2020.





## Studying Dehydration Reduction Strategies During Hajj and Umrah Rituals: Behaviours used by the pilgrims and Barriers faced them

Sarah Hakeem

Department of community nursing and healthcare, Faculty of Nursing, Umm Al-Qura University

\*Corresponding author: E-mail (shhakeem@uqu.edu.sa)

### دراسة استراتيجيات الحد من الجفاف أثناء الحج والعمرة: السلوكيات التي يتبعها الحجاج والعوائق التي تواجههم

سارة هشام حكيم

قسم تمريض المجتمع والرعاية الصحية، كلية التمريض، جامعة أم القرى

#### الملخص

مقدمة البحث: يعد الجفاف أحد المشكلات الشائعة أثناء الحج والعمرة، حيث يؤدي عدم تناول كمية كافية من السوائل إلى تحدٍ كبير للرعاية الصحية، خاصة في الظروف الحارة، مما يؤكد الحاجة إلى الوقاية لتجنب العواقب الوخيمة. أهداف البحث: تهدف هذه الدراسة إلى معرفة الاستراتيجيات التي يستخدمها الحجاج لتقليل الجفاف وتحديد العوائق التي تمنعهم من الحفاظ على رطوبة الجسم أثناء مناسك الحج والعمرة.

منهجية البحث: تم تلقي إجمالي 89 ردًا من الحجاج الذين أدوا فريضة الحج أو العمرة والذين تزيد أعمارهم عن 18 عامًا. ثم تم إجراء التحليل الوصفي والتكراري باستخدام برنامج SPSS.

نتائج البحث: أظهرت النتائج أنَّ عددًا كبيراً من المشاركين يميلون إلى تجنب شرب السوائل مع عدم حمل زجاجات المياه؛ بدلاً من ذلك أظهر المشاركون تفضيلهم لتجنب أداء المناسك في أوقات ذروة الحرارة والأزدحام. بالإضافة إلى ذلك، وضح المشاركون تجنبهم لشرب السوائل لمنع زيارات المرحاض. ومع ذلك، فإن توفير توزيع المياه ومشاهدة الآخرين يشربون السوائل برزت كمحفزات محتملة.

الاستنتاج: هذه النتائج تضع الأساس لتطوير برامج تعليمية موجبة لتعزيز ممارسات تجنب الجفاف للحجاج. وهذا بدوره يمكن أن يساهم في خفض تكلفة العلاج، وتحسين الاستدامة الصحية، وتعزيز التجربة الشاملة للحجاج، وهو أحد أهداف رؤية المملكة 2030.

#### Abstract

Dehydration is one of the common issues during Hajj and Umrah. Inadequate fluid intake leads to a significant healthcare challenge, especially in hot conditions, underscoring the need for prevention to avoid severe consequences.

This study aimed to investigate the strategies used by pilgrims to reduce dehydration and to identify the barriers that hinder them from maintaining proper hydration during Hajj and Umrah rituals.

Methodology: A total of 89 responses were received from pilgrims who did the Hajj or Umrah and older than 18 years. A descriptive and frequencies analysis was then conducted via SPSS software.

The findings revealed that a significant number of participants tend to avoid drinking fluids while not carrying water bottles; instead favoring the avoidance of peak heat and crowded conditions. Additionally, participants avoid drinking

fluids to prevent toilet visits. However, the provision of water distribution and witnessing others drinking water emerged as potential motivators.

These results lay the groundwork for developing targeted education programs to enhance pilgrims' hydration practices. This, in turn, can contribute to reducing the cost of treatment, improving health sustainability, and enhancing the overall experience of the pilgrims, which is one of the Kingdom's Vision 2030 objectives.

**Keywords:** Dehydration, Pilgrims, Behaviors, Barriers.

## 1. Introduction

Millions of pilgrims participating in Hajj and Umrah are facing the heat stress risks that have led to health impacts and could worsen due to global warming. During the hottest months of August, September, and October, extreme heat thresholds may be significantly exceeded, with the highest risk increase in September, which could negatively affect pilgrimage performance (Saeed et al., 2021, Ahmed et al., 2006). Heat-related illnesses vary from mild symptoms like weakness, dizziness, and fatigue (heat edema) to severe conditions such as fainting, extreme exhaustion, and multiple system complications leading to coma or death (heat stroke) (Barrow and Clark, 1998). Hot conditions and heat stress are linked to higher mortality and morbidity rates, while also having a detrimental impact on mental health. Additionally, increased heat stress can lead to reduced physical work capacity and impaired motor-cognitive functions, resulting in decreased productivity and an elevated risk of occupational health issue (Ebi et al., 2021).

"Dehydration" in clinical practice is defined as the insufficiency of total bodily water. It is evidently common and associated with significant costs in healthcare (Lacey et al., 2019). Untreated dehydration progresses from mild to severe stages. While mild dehydration can be easily treated when its initial symptoms, including a dry mouth, sleepiness, thirst, reduced urine output, dry skin, headache, constipation, and dizziness or light-headedness, are recognized, heatstroke is a medical emergency that can be fatal (Bettencourt Pires et al., 2016).

Frequent triggers for dehydration encompass strenuous physical activity, particularly in hot conditions, severe diarrhea, vomiting, high fever, or excessive sweating. A lack of adequate fluid intake during exercise, or in hot environments, even without physical activity, can also lead to dehydration, which are all relevant to the context of performing Hajj and Umrah rituals (Bettencourt Pires et al., 2016). The primary approach to managing dehydration is prevention, involving early detection and treatment of mild dehydration symptoms. Mild heat-related symptoms can be addressed with hydration, rest, and avoiding hot conditions. In contrast, heat stroke, a severe and life-threatening condition, requires immediate medical attention (Bettencourt Pires et al., 2016, Barrow and Clark, 1998).

The primary objective of this research is to investigate the strategies used by pilgrims to reduce dehydration when they perform the Hajj and Umrah rituals. Additionally, the study seeks to identify the barriers that hinder pilgrims from maintaining proper hydration during these religious journeys.

The findings from this research will be instrumental in devising efficient strategies to protect the pilgrims from the dehydration health consequences. Thus, reducing the cost of treatment and improving health sustainability. Moreover, ensuring adequate hydration will enable pilgrims to carry out their religious obligations with sincerity and focus, thus enhancing the spiritual dimension of their pilgrimage experience of the pilgrims, which is one of the main objectives of the Kingdom's Vision 2030.

## 2. Methodology

### *Study participants*

All pilgrims who did the Hajj or Umrah and aged older than 18 years were included and considered appropriate for the study. A total of 89 responses to the questionnaire were completed and used for the statistical analysis.

### *Data collection tools*

A cross-sectional self-reported survey questionnaire that focused on behaviors, and barriers was completed by pilgrims. The questionnaire included 38 questions, with three domains (i) demographic (n = 10), (ii) behaviors (n = 14), and (iii) barriers (n = 14). The behaviors questions were adapted (to be more suitable for Hajj and Umrah rituals) based on the questionnaire that conducted by Decher et al. (2008) taking into account the advices from Ministry of the Health for the pilgrims. Regarding the barriers questions, they were modified questions from the questionnaire that validated by Veilleux et al. (2020). The modified questionnaire was reviewed and approved by expertise in the field.

### *Statistical analysis*

Statistical Analysis was conducted using SPSS version 7. The categorical data were presented as percentages (with the corresponding sample size). A  $\chi^2$  test was used to test the variance between the participants' responses according to the rituals they did (Hajj or Umrah) as well as between participants' responses and their demographic characteristics.

## 3. Results

### *Participants characteristics*

A total of 89 responses were included in the analysis, with 75% of them depending on the Umrah ritual. However, no significant differences were found in the characteristics and responses of participants who performed Hajj and Umrah. Participant characteristics are shown in Table 1. Approximately 60% of the participants were female, aged between 30 to 39 years old, married, had completed their bachelor's degrees, considered themselves healthy, and had a normal BMI. Participants were also asked about the month when they performed the rituals. The majority of the responses indicated that the rituals were done between June and October due to Ramadan and Hajj occurring during the last 10 years. However, if it was not Hajj month or performing Umrah in Ramadan (since they could not choose the month), participants were more likely to perform Umrah between January and March when the weather is cooler in Makkah.

### *The strategies used by pilgrims to reduce dehydration when they do the Hajj and Umrah rituals.*

A total of 14 questions about the strategies used to reduce dehydration during Hajj and Umrah rituals were posed to the participants. They had to choose one of the five answers ranging from 'not at all like me' to 'very much like me' (see Table2).

The majority of the responses indicated that participants tend to avoid drinking fluids. For example, 33% of them reported, 'I only drank water when I felt thirsty,' and 56% reported, 'I used to drink water and fluids once I finished doing the rituals,' while 46% reported that they do not carry a water bottle with them during the rituals. However, they preferred avoiding the peak hot time and crowded conditions when they performed the rituals (49% and 46%, respectively, responded 'very much like me'). They also preferred finding shaded places when performing the rituals (44% responded 'very much like me') instead of carrying an umbrella or wearing hats (48% responded 'not at all like me'). Finally, participants' responses were mostly evenly distributed regarding nutritional questions related to hydration.

### *The barriers that hinder pilgrims from maintaining proper hydration during Hajj and Umrah rituals.*

A total of 14 questions about the barriers hindering pilgrims from maintaining proper hydration during Hajj and Umrah rituals were posed to the participants (three of the questions were reverse questions). Participants had to choose one of the five answers ranging from 'not at all like me' to 'very much like me' (see Table 3). Participants' responses indicated that they do not think much about drinking fluids. Additionally, they tend to avoid drinking fluids to prevent going to the toilet (34%, 28%, and 25%), as well as tend to avoid carrying water bottles with them (32% and 30%). On the other hand, they reported that the existence of water distribution (27%) and seeing other people drinking water (23%) might encourage them to drink water, while having apps to remind them to drink water did not help them (45% and 37%).

*The association between strategies used by pilgrims to reduce dehydration when they do the Hajj and Umrah rituals and their demographic characteristics.*

No significant differences were found between participant responses to the strategies used to reduce the dehydration when they do the Hajj and Umrah rituals according to their sex, age, marital status, education, and health status.

*The association between barriers that hinder pilgrims from maintaining proper hydration during Hajj and Umrah rituals and their demographic characteristics.*

No significant differences were found between participant responses to barriers that hinder them from maintaining proper hydration when they do the Hajj and Umrah rituals according to their sex, age, marital status, education, and health status.

Table 1: Participants demographic characteristics

Participants	n	%
Sex		
Male	54	60.7
Female	35	39.3
Age		
18-29	27	30.3
30-39	35	39.3
40-49	17	19.1
>50	10	11.2
Marital status		
Single	26	29.2
Married	58	65.2
Divorced/ widowed	5	5.6
Education		
Less than high school	4	4.5
Diploma	5	5.6
Bachelor's degree	45	50.6
High education	35	39.3
Health status		
Very good	63	70.8
Pretty good	13	14.6
Have chronic disease but take care of their health	10	11.2
Have chronic disease but don't care	3	3.4
BMI		
Underweight	6	6.7
Normal	47	52.8
Overweight	22	24.7
Obese	14	15.7

Table 2: The strategies used by pilgrims to reduce dehydration when they do the Hajj and Umrah rituals.

The strategies	The responses				
	Not at all like me	Nit much like me	Somewhat like me	Mostly like me	Very much like me
I only drank fluid when I felt thirsty % (n)	10 (9)	19 (17)	19 (17)	18 (16)	33 (30)
I used to drink fluid before doing the rituals % (n)	17 (15)	15 (13)	23 (20)	18 (16)	28 (25)
I used to carry a water bottle to stay hydrated during doing the rituals % (n)	46 (41)	7 (6)	23 (20)	11 (10)	14 (12)
I used to drink fluid and fluids once I finish doing the rituals % (n)	3 (2)	5 (4)	14 (12)	23 (20)	56 (50)
I tried my best to drink fluid and fluid every hour while I did the rituals % (n)	30 (27)	18 (16)	27 (24)	15 (13)	10 (9)
I needed to dink more fluid when I did the rituals during the peak hot times % (n)	16 (14)	15 (13)	24 (21)	19 (17)	27 (24)
I needed to drink more fluid when I did the rituals while it's crowded than usual % (n)	20 (18)	17 (15)	25 (22)	23 (20)	16 (14)
I needed to drink more fluid when I did the rituals longer than usual % (n)	10 (9)	12 (11)	21 (19)	30 (27)	26 (23)
I tried to avoid doing the rituals during the peak hot time % (n)	9 (8)	5 (4)	18 (16)	19 (17)	49 (44)
I tried to avoid doing the rituals during the peak crowded time % (n)	7 (6)	10 (9)	15 (13)	23 (20)	46 (41)
I tried my best to by find shaded places when I did the rituals % (n)	10 (9)	6 (5)	21 (19)	19 (17)	44 (39)
I carried an umbrella/ wore a hat during the daytime when I did the rituals % (n)	48 (43)	14 (12)	10 (9)	10 (9)	18 (16)
I helped my body prepare to stay hydrated while I am doing the rituals in the hot weather by reducing the intake of salty and spicy food before doing the rituals % (n)	23 (20)	19 (17)	24 (21)	14 (12)	21 (19)
I tried my best to increase consumption of food that contain water % (n)	25 (22)	20 (18)	24 (21)	12 (11)	19 (17)

Table 3: The barriers that hinder pilgrims from maintaining proper hydration during Hajj and Umrah rituals

The barriers	The responses				
	Not at all like me	Nit much like me	Somewhat like me	Mostly like me	Very much like me
I have a habit of drinking fluid regularly* % (n)	15 (13)	19 (17)	25 (22)	16 (14)	26 (23)
I'm often too busy to go get a drink of water % (n)	20 (18)	26 (23)	30 (27)	12 (11)	11 (10)
I'm used to drinking fluids regularly; I don't even have to think about it* % (n)	14 (12)	26 (23)	24 (21)	21 (19)	16 (14)
I'm often too lazy to drink more liquid % (n)	24 (21)	23 (20)	26 (23)	19 (17)	9 (8)
I avoid drinking fluids if I'm going to be somewhere without a bathroom % (n)	14 (12)	9 (8)	19 (17)	25 (22)	34 (30)
I avoid drinking fluids because going to bathroom is time consuming especially when its crowded % (n)	17 (15)	14 (12)	18 (16)	24 (22)	28 (25)
I don't like having to go to the bathroom all the time and repeat ablution % (n)	12 (11)	11 (10)	12 (11)	29 (26)	25 (31)
I don't want to carry a water bottle % (n)	23 (20)	11 (10)	19 (17)	16 (14)	32 (28)
I carry a bottle with me to make hydration easier* % (n)	25 (22)	14 (12)	26 (23)	12 (11)	24 (21)
Carrying a water bottle is annoying % (n)	25 (22)	9 (8)	16 (14)	20 (18)	30 (27)
I'm more likely to drink fluid when there is water distribution % (n)	15 (13)	16 (14)	27 (24)	20 (18)	23 (20)
If there is an app remind me about my fluid intake, I'm more likely to stay hydrated % (n)	45 (40)	14 (12)	17 (15)	16 (14)	9 (8)
Seeing other people drinking fluid helps me drink more % (n)	18 (16)	17 (15)	23 (20)	23 (20)	20 (18)
Having an app monitoring my fluid consumption helps me stay hydrated % (n)	37 (33)	17 (15)	21 (19)	15 (13)	10 (9)

\*Reverse questions

#### 4. Discussion

The 14 questions survey was designed comprehensively to assess individuals' behaviours and preferences concerning fluid intake during significant religious rituals. This comprehensive questionnaire investigated various aspects of participants' practices, including their fluid intake behaviours, methods to reduce thirst, and strategies to avoid dehydration., offering valuable insights into potential areas for improvement or targeted interventions in promoting healthier practices.

Notably, a substantial number of participants exhibited a tendency to avoid drinking fluids, with 33% reporting consumption only when thirsty and 46% admitted to not carrying a water bottle during the rituals, potentially influenced by challenges in repeating ablution due to crowded conditions, despite available toilets. Participants demonstrated a conscious effort to avoid dehydration by avoiding peak heat and crowded times. Interestingly, a preference for seeking shaded places (44%) over conventional methods like carrying umbrellas or wearing hats (48%) emerged, possibly influenced by religious clothing restrictions during these rituals as well as their need to use their hand during the ritual. The results of the study, which investigated the barriers hindering pilgrims from maintaining proper hydration during Hajj and Umrah rituals through a comprehensive set of 14 questions, reveal several noteworthy insights. A predominant theme in participants' responses is a tendency to not prioritize fluid intake, as indicated by their responses suggesting limited consideration for drinking fluids. Interestingly, a significant proportion of participants acknowledged avoiding drinking fluids to prevent the inconvenience of using public toilets. Moreover, a notable percentage reported avoiding carrying water bottles, which may contribute to challenges in staying adequately hydrated during the rituals. Conversely, participants indicated that the presence of water distribution (27%) and observing others drinking water (23%) could serve as encouraging factors for them to drink more fluids. Surprisingly, despite the prevalence of health-related apps, a substantial majority reported that reminders from such apps did not effectively contribute to their hydration practices. These findings highlight the multifaceted nature of barriers to proper hydration during religious rituals.

Raising pilgrims' awareness of the impact of dehydration on their health is a crucial aspect of ensuring their well-being during Hajj and Umrah rituals. Pilgrims often come from diverse regions with varying climates and may not be accustomed to the hot conditions. Therefore, educational campaigns play a vital role in informing pilgrims about the importance of maintaining proper hydration levels in such challenging weather. These initiatives offer valuable information on recognizing dehydration signs, the significance of adequate water consumption, and strategies for staying hydrated throughout the pilgrimage. Increased awareness empowers pilgrims to take proactive measures to safeguard their health and contributes to the overall success and safety of the pilgrimage experience.

#### *Strength and limitation*

The research strength is evident in the approval and validation of the questionnaire, ensuring their reliability and accuracy. This questionnaire comprehensively covered various strategies related to the performance of the rituals of Hajj and Umrah. However, the research has certain limitations that should be acknowledged. Firstly, all responses were gathered exclusively from participants living in Saudi Arabia who used to live in the hot weather, potentially limiting the generalizability of findings to a broader, more diverse population, especially those who come from different climates. Furthermore, an additional limitation lies in the relatively small total number of participants. Acknowledging these limitations is essential for a nuanced interpretation of the research outcomes within the context of its demographic scope and sample size.

### **5. Conclusions and Recommendations**

In conclusion, this study illuminates the strategies and barriers associated with hydration among pilgrims during Hajj and Umrah rituals. The research findings are pivotal for developing effective strategies to protect pilgrims from the health consequences of dehydration, thereby reducing treatment costs and enhancing health sustainability. Adequate hydration not only facilitates the performance of religious obligations with sincerity and focus but also contributes to an enriched pilgrimage experience, which is an integral aspect aligned with the objectives of the Kingdom's Vision 2030. To address

dehydration risks, a comprehensive strategy is recommended, encompassing education for pilgrims, particularly those from diverse climates, regarding the avoidance of dehydrating by avoiding hot and crowded time as well as increasing the intake of foods and the promotion of water-rich foods. Active encouragement for increased fluid intake such as water distribution during rituals and in crowded conditions is highlighted as a crucial step to address dehydration concerns.

## References

- AHMED, Q. A., ARABI, Y. M. & MEMISH, Z. A. 2006. Health risks at the Hajj. *Lancet*, 367, 1008-15.
- BARROW, M. W. & CLARK, K. A. 1998. Heat-related illnesses. *American family physician*, 58, 749-756.
- BETTENCOURT PIRES, M., VILEMAR MAGALHAES, J. & GUPTA, P. 2016. Heat waves in nonconventional areas, climate change and disease load: A review. *Journal of Cell and Tissue Research*, 16, 5705-5711.
- DECHER, N. R., CASA, D. J., YEARGIN, S. W., GANIO, M. S., LEVREAU, M. L., DANN, C. L., JAMES, C. T., MCCAFFREY, M. A., O'CONNOR, C. B. & BROWN, S. W. 2008. Hydration status, knowledge, and behavior in youths at summer sports camps. *International Journal of Sports Physiology and Performance*, 3, 262-278.
- EBI, K. L., CAPON, A., BERRY, P., BRODERICK, C., DE DEAR, R., HAVENITH, G., HONDA, Y., KOVATS, R. S., MA, W. & MALIK, A. 2021. Hot weather and heat extremes: health risks. *The lancet*, 398, 698-708.
- LACEY, J., CORBETT, J., FORNI, L., HOOPER, L., HUGHES, F., MINTO, G., MOSS, C., PRICE, S., WHYTE, G. & WOODCOCK, T. 2019. A multidisciplinary consensus on dehydration: definitions, diagnostic methods and clinical implications. *Annals of medicine*, 51, 232-251.
- SAEED, F., SCHLEUSSNER, C.-F. & ALMAZROUI, M. 2021. From Paris to Makkah: heat stress risks for Muslim pilgrims at 1.5° C and 2° C. *Environmental Research Letters*, 16, 024037.
- VEILLEUX, J. C., CALDWELL, A. R., JOHNSON, E. C., KAVOURAS, S., MCDERMOTT, B. P. & GANIO, M. S. 2020. Examining the links between hydration knowledge, attitudes and behavior. *European journal of nutrition*, 59, 991-1000.



## Nutritional knowledge among Hajj and Umrah service providers in the Kingdom of Saudi Arabia

Mai Adil Ghabashi

Clinical Nutrition department, Umm Al-Qura University

\*Corresponding author: E-mail (maghabashi@uqu.edu.sa)

## المعرفة الغذائية لدى مقدمي الخدمات لضيوف الرحمن من الحجاج والمعتمرين في المملكة العربية السعودية

مي عادل غباشي

قسم التغذية الإكلينيكية، جامعة أم القرى

### الملخص

الحج إلى بلد الله الأمين أحد أكبر التجمعات السنوية في العالم، متميزاً بحدوثه في زمن محدد ومكان محدد بمكة والمشاعر المقدسة، وله تأثير كبير على الصحة العامة للمجتمع. ويعتبر مستوى المعرفة الغذائية لدى مقدمي الخدمات والرعاية لضيوف الرحمن من الجوانب المهمة التي يجب تسليط الضوء عليها تحقيقاً للتميز الصحي في هذا الحدث المهم. ذلك أن المعرفة الغذائية لدى مقدمي الخدمات والرعاية لضيوف الرحمن يمكن ان تُؤدي دوراً كبيراً في تمكينهم من اتخاذ الخيارات الصحيحة لمعالجة مشاكل التغذية لدى الحجاج أثناء قضاء مناسكهم. ولكن -في الوقت الراهن (1445هـ) - لا يوجد على حد علم الباحث معلومات حول مستوى المعرفة الغذائية لدى مقدمي الخدمات لحجاج بيت الله الحرام. وعليه فإن هذه الدراسة تهدف الى تغطية هذه الثغرة البحثية من خلال تقديم تقييم أولي للمعرفة الغذائية لدى مقدمي الخدمات للحجاج والمعتمرين. علاوةً على تحليل العلاقة بين مستوى معرفتهم الغذائية والصفات الديموغرافية.

منهجية البحث قامت على عمل دراسة مسح مقطعية حيث كانت أداة القياس استبانة تم نشرها لدى الفئة المستهدفة عبر الإنترنت باستخدام تقنية الكرة الثلجية. كان عدد المشاركين في هذه الدراسة 357 فرداً من مقدمي الخدمات والرعاية لضيوف الرحمن (49.3% منهم كانوا من الرجال و 50.7% من النساء)، بمتوسط عمر يناهز 35 عاماً ونسبة جيدة منهم تحمل شهادة جامعية (68.6%). وجدت الدراسة أن المعرفة الغذائية تعتبر متوسطة لدى الفئة المستهدفة حيث بلغ المتوسط فيها 9.1 من أصل 18 نقطة وكان هناك تباين في المعرفة الغذائية، إذ كانت معرفتهم بمجموعي النشويات (الكربوهيدرات) والبروتين أعلى من معرفتهم بمجموعة الدهون. علاوة على ذلك، كانت المعرفة الغذائية لدى مقدمي الخدمة من الإناث أعلى بشكل ملحوظ من ذلك لدى الذكور. وأشارت هذه الدراسة إلى أن مستوى المعرفة الغذائية كان مرتبطاً بشكل طردي مع مستوى التعليم بينما ارتبط بشكل عكسي مع مؤشر كتلة الجسم. لذلك توصي هذه الدراسة بتصميم برامج لتعزيز الوعي الغذائي لدى الفئة المستهدفة. كما يوصى بقياس فعالية استخدام وسائل التواصل الاجتماعي والأجهزة الذكية كوسيلة لتقديم مثل هذه البرامج.

### Abstract

**Background:** The Hajj pilgrimage to Makkah, Kingdom of Saudi Arabia (KSA), is one of the largest annual mass gatherings in the world and has a strong impact on international public health. To achieve health excellence, it is important to shed light on the level of nutritional knowledge among Hajj and Umrah service providers which can play a



crucial role in addressing pilgrims' nutritional problems during the pilgrimage. To the best of my knowledge, as of 2022, there is a lack of information regarding the level of nutritional knowledge of Hajj and Umrah service providers.

**Aims:** This research aimed to cover this gap by providing the first preliminary assessment of the nutritional knowledge of Hajj and Umrah service providers in association with their demographic characteristics.

**Methods:** A cross-sectional study was carried out using an online survey, which used a validated questionnaire designed to assess nutritional knowledge. It was distributed among Hajj and Umrah service providers using the snowball technique.

**Results:** This study involved 357 Hajj and Umrah service providers. 176 participants were men (49.3%) and 181 were women (50.7%) with a mean age of  $35.0 \pm 11.3$  years. 245 participants (68.6%) had a university degree. The average score of nutritional knowledge on macronutrients and energy composition of food was  $9.1 \pm 2.4$  out of 18, categorising the level of nutritional knowledge of the participants to be *moderate*. There was a variation in terms of nutritional knowledge. That is, their knowledge of the starch (carbohydrate) and protein groups was higher than that of the fat group ( $p < 0.001$ ). Moreover, the nutritional knowledge of female service providers was significantly higher than that of the males ( $p = 0.004$ ). Higher scores of nutritional knowledge in this sample were positively associated with the level of education ( $p < 0.001$ ), while a negative borderline association with BMI was detected ( $p = 0.05$ ).

**Conclusion and recommendations:** The findings of the present study highlight the importance of designing an appropriate programme for improving nutritional knowledge in Hajj and Umrah service providers. To achieve health excellence, it is recommended to test the effectiveness of digital nutrition education interventions targeting this group.

**Keywords:** Nutritional knowledge, Hajj and Umrah, service providers

## 1. Introduction

Hajj and Umrah, two significant pilgrimages to Makkah, Saudi Arabia, serve as large Islamic gatherings that have a strong impact on international public health. Pilgrims from over 160 countries come to the city of Makkah throughout the year, congregating in one specific area to perform a number of Islamic rituals. In 2022, the Kingdom of Saudi Arabia hosted over 24 million Hajj and Umrah visitors (Statistics, 2023). This number is projected to increase, as the Saudi Vision 2030 predicts hosting approximately 30 million pilgrims annually. Many of the pilgrims attending the Hajj and Umrah suffer from health conditions and non-communicable diseases (NCDs). For instance, a relevant study reported that 41% of Umrah visitors were diabetic patients and 31.9% had hypertension (Ahmed *et al.*, 2019). Moreover, due to the rituals and practices involved in the pilgrimage, performing the Hajj and Umrah is often physically and mentally draining, which could involve physical stressors combined with changes in sleeping and eating habits (Centers for Disease Control and Prevention, 2023). These factors could exacerbate the health complications associated with NCDs.

The complications of NCDs are considered a major cause of pilgrims' hospitalization and mortality (Yezli *et al.*, 2021). The KSA provides free healthcare services for all pilgrims during the Hajj and Umrah periods (Aldossari, Aljoudi, and Celentano, 2019), imposing an economic burden on the healthcare system. Managing the symptoms of chronic diseases is therefore important in order to reduce hospitalization and mortality rates (McPhail, 2016). A healthy dietary pattern is one important factor for managing such complications associated with chronic diseases (Neuhouser, 2019). A recent study conducted in the KSA pointed out the importance of taking the pilgrims' dietary needs into consideration, and this includes providing special meals and increasing nutrition knowledge amongst the public (Turkistani, 2022).

Nutrition knowledge (NK) is one of the factors that can contribute to improving dieting quality and ensuring better health and capability (Koch, Hoffmann, and Claupein, 2021), as well as playing a crucial role in weight management

(Shimokawa, 2013). That is, individuals who are aware of the nutritional content of foods will often make healthier choices that support their weight loss or management (Laz *et al.*, 2018). This is important, as having an ideal body weight is found to be a strong predictor of a better quality of life (Stephenson *et al.*, 2021). In relation to Hajj and Umrah, nutrition knowledge is crucial for both pilgrims and Hajj and Umrah service providers, as this knowledge can assist in making informed dietary choices that support specific health conditions. This in turn, can help manage any associated symptoms and health complications (Jafari *et al.*, 2016). It is also suggested that adequate nutrition knowledge provided by Hajj and Umrah service providers may lead to better patient outcomes and improved quality of care, which consequently could increase the level of service satisfaction (Al Shammari *et al.*, 2021). It is therefore expected that service providers with better health would be more capable of providing better services to pilgrims during Hajj and Umrah periods. Currently, there is limited data concerning several aspects related to the healthcare services provided to the pilgrims. This includes the nutrition knowledge of the service providers, the special dietary needs of pilgrims, and their satisfaction with meals provided during the Hajj and Umrah periods (Aldossari, Aljouidi, and Celentano, 2019). The KSA prioritizes offering high-quality multidiscipline services and ensuring health excellence (Aljohani *et al.*, 2022). Thus, the Institute of Hajj and Umrah Research has encouraged conducting studies that would help in improving the quality of services provided to pilgrims and allowing a better experience during their Hajj and Umrah journeys. In response to this, the present study aims to fill one of the current gaps in this area of study, by providing a preliminary assessment of the basic nutrition knowledge of Hajj and Umrah service providers. It is important to note that the field of nutrition knowledge is vast, with several domains such as food groups, healthy food choices, and dietary recommendations of nutrition experts. As a preliminary assessment, the present study aims to focus on macronutrients and energy composition of foods. The findings of this study will subsequently help in providing an understanding of the basic elements of nutrition knowledge within the targeted group and will be important for informing future research aimed at improving dietary services to pilgrims.

## 2. Methodology

This study targeted Hajj and Umrah service providers operating for  $\geq 18$  years, who were working in this sector during the past year (2022/2023) in the Kingdom of Saudi Arabia. The study used the revised form of the General Nutrition Knowledge Questionnaire (GNKQ-R), which is a widely used tool to assess the GNK in adults. The original questionnaire was developed in the United Kingdom in 1994 (Parmenter and Wardle, 1999). It was also, used in other countries including Australia (Hendrie, Cox, and Coveney, 2008), Uganda (Bukonya, 2017), and China (Gao *et al.*, 2021). The GNKQ was revised and validated to assess GNK in British Adults (Kliemann *et al.*, 2016) as well as other populations including Malaysian (Hazwani *et al.*, 2023) and Turkish (Eksi, 2022) adults. In a recent study by Bataineh and Attlee (2021), the revised version of the questionnaire was translated into Arabic language and validated among an Arabic-speaking population. This 86-item questionnaire is a comprehensive tool to assess several domains of nutrition knowledge. Specifically, it assesses four main aspects of nutrition knowledge: food groups, food choices, dietary recommendations, and diet-related disease (Bataineh and Attlee, 2021). The GNKQ-R can be used differently based on the study objectives, and since the present study aimed to assess nutrition knowledge of the basic macronutrients, questions from the food group scale were used, comprising of 18 items.

The questionnaire was digitized using Google Forms and subsequently distributed online to Hajj and Umrah service providers via WhatsApp. The snowball technique was employed to disseminate this digital survey, which aimed to

explore the nutrition knowledge of the target group while ensuring the absence of personal information collection. Specifically, participants were not requested to provide their names, identification numbers, phone numbers, or email addresses. It was also explicitly communicated to participants that their involvement is voluntary and intended solely for research purposes, with the assurance of strict confidentiality regarding the handling of their responses. The included questions cover the knowledge regarding the macronutrient composition of food items (i.e. starch/carbohydrate, protein, and fat). It also covered other related aspects, including the energy density of specific food items and processed food. The answers were divided into three categories: correct, incorrect, and not sure. According to the scoring system of this tool, each correct answer counts as one point. Incorrect answers or being *not sure* were counted as zero points.

Upon completion, the total score for general knowledge was calculated, wherein the maximum score was 18 points. The level of nutrition knowledge was classified using the modified Bloom's cut-off points (Yimer, 2014). That is, a score of 80-100% of correct responses (14.4-18 points) indicates a *good* NK, a score of 50-79% (9-14.3 points) was of a *moderate* level of NK, and a score less than 50% of the correct responses (<9 points) denoted a *low* level of NK. To provide further details, subscales regarding the knowledge of macronutrient composition in food items were calculated. The maximum knowledge scores of carbohydrate, protein, and fat were 5, 6, and 4 points respectively. The present study also collected demographic data, including age, sex, nationality, education, and subjectively reported weight and height. The data on education were categorized as a dichotomized variable (*with a university degree vs without a university degree*). Weight and height were used to calculate BMI using the following equation; weight (in kilograms) / height<sup>2</sup> (in meters), which was then defined as follows: BMI < 18 indicates *underweight*, BMI ranging between 18.5 - 24.9 indicates *normal body weight*, BMI ranging between 25.0 - 29.9 indicates *overweight*, and BMI ≥ 30 indicates *obesity*.

Statistical analysis: The normality of the data was checked and normally distributed, except for BMI; thus, log transformation was applied to normalize the distribution of BMI values. In addition, one-way ANOVA was used to check if there was a difference in macronutrient knowledge scores. Continuous data were presented as mean (SD), while categorical data were presented as frequency (%). The data were compared according to sex. Comparisons between groups were performed using an independent t-test for continuous variables, while chi-squared was used to compare categorical variables. In addition, the associations between nutrition knowledge scores and the demographic characteristics of the study participants were examined via multiple regression analysis. A beta coefficient with 95% Confidence Intervals (CI) was calculated to identify variables associated with nutrition knowledge scores. The level of significance was set at (<0.05).

### 3. Results

The findings of the current study are presented in Tables 1, 2, and 3, and also in Figures 1, 2, and 3. Table 1 represents the demographic characteristics of the participants. As shown, of the total sample size (n=357), 49.3% (n=176) were males and 50.7% (n=181) were females. The mean age was 35.1±11.3 and the majority (80.7% (n=288)) were of Saudi Arabian nationality. The mean BMI of the participants was 27.6±6.0. There was a high prevalence of overweight and obesity among the participants, representing 63.9% of the total sample; this was more prevalent in men compared to women (69.9% vs 58.0%, p=0.04) (Table 1).

Table 2 shows the nutrition knowledge of the participants, with an emphasis on macronutrients. The average total score of nutrition knowledge in the current sample was 9 ± 2.4 out of 18 points. This was significantly higher in females compared to males (9.3± 2.3 vs 8.5 ± 2.5, p=0.004). Moreover, more than half of the participants (58.3%) had a moderate level of nutritional knowledge. There was a variation in the macronutrient knowledge among participants with higher

scores for starch and protein compared to fat ( $p=0.001$ ). In comparison to men, women had a slightly higher knowledge of Starch ( $3.3\pm 1.1$  vs  $3.5\pm 0.9$ ,  $p=0.03$ ) and protein groups ( $3.2\pm 1.1$  vs  $3.5\pm 1.1$ ,  $p=0.01$ ) (Table 2).

Table 1. Demographic and anthropometric characteristics of study participants

3	All n=357		Males n=176		Females n=181		p <sup>1</sup>
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
Age, years	35.1	(11.3)	33.1	(11.1)	36.0	(11.1)	0.06
Nationality, Saudi, n (%)	288.0	(80.7)	139.0	(79.0)	149.0	(82.3)	0.5
Education, with a university degree, n (%)	245.0	(68.6)	120.0	(68.1)	125.0	(69.1)	0.8
BMI, kg/m <sup>2</sup>	27.6	(6.0)	28.7	(6.3)	26.6	(5.9)	0.004
Weight status, underweight, n (%)	17.0	(4.8)	5.0	(2.8)	12.0	(6.6)	0.8
Weight status, normal, n (%)	112.0	(31.4)	48.0	(27.3)	64.0	(35.4)	0.1
Weight status, overweight, n (%)	123.0	(34.5)	68.0	(38.6)	55.0	(30.4)	0.1
Weight status, obesity, n (%)	105.0	(29.4)	55.0	(31.3)	50.0	(27.6)	0.1
Total overweight and obesity, n (%)	228.0	(63.9)	123.0	(69.9)	105.0	(58.0)	0.02

All data are mean (SD) unless indicated. <sup>1</sup>Comparison between groups using independent t-test for continuous normally distributed variables and chi-squared for categorical variables.

Table 2. Nutrition knowledge of study participants

	All n=357		Males n=176		Females n=181		p <sup>1</sup>
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
Overall NK score	9.0	(2.4)	8.5	(2.5)	9.3	(2.3)	0.004
High level of NK, n (%)	5.0	(1.4)	1.0	(0.6)	4.0	(2.2)	0.1
Moderate level of NK, n (%)	208.0	(58.3)	95.0	(54.0)	113	(62.4)	0.1
Low level of NK, n (%)	144.0	(40.3)	80.0	(45.5)	64.0	(35.4)	0.05
Macronutrient NK score <sup>2</sup>	8.0	(2.1)	7.6	(2.1)	8.3	(2.0)	0.001
NK of Starch group score	3.4	(1.0)	3.3	(1.1)	3.5	(0.9)	0.03
NK of Protein group score	3.4	(1.2)	3.2	(1.1)	3.5	(1.1)	0.01
NK of Fat group score	1.1	(0.6)	1.1	(0.9)	1.2	(0.7)	0.1

All data are mean (SD) unless indicated. <sup>1</sup>Comparison between groups using independent t-test for continuous normally distributed variables and chi-squared for categorical variables; <sup>2</sup>One-way ANOVA test was used to determine whether there are statistically significant differences between the means of nutrition knowledge scores regarding macronutrients (starch, protein, fat).

As indicated in Table 3, the nutrition knowledge was associated with many demographic characteristics of the study participants. For example, the multiple regression analysis detected a significant association between gender, education, and nationality with the nutrition knowledge scores.

Nationality was found to be a significant predictor of nutrition knowledge ( $\beta=0.14$ ,  $p=0.01$ ). That is, Saudi participants had a higher nutrition knowledge compared to non-Saudi participants. Additionally, a significant positive association was found between gender and nutrition knowledge ( $\beta=0.12$ ,  $p=0.01$ ), indicating that women tended to have higher levels of nutrition knowledge compared to men. A further associated factor with nutrition knowledge was education ( $\beta=0.20$ ,  $p=0.005$ ). Participants with a university degree had more nutrition knowledge compared to their counterparts without a university degree. Interestingly, there was an inverse association between the level of knowledge and BMI at border level of significance ( $\beta=0.10$ ,  $p=0.05$ ). That is, higher nutritional knowledge indicated a lower BMI, suggesting that nutrition knowledge might be a protective factor against obesity. In this study, age was not associated with nutrition knowledge. These variables account for 20% of the variance in the nutrition knowledge score ( $r^2=0.20$ ), in which the  $r^2$  value

indicates that 20% of the variance in the dependent variable (nutrition knowledge score) is explained by the independent variables (demographic characteristics).

Table 3. Relationship between General Nutrition Knowledge Scores and participant demographics<sup>1</sup>

	$\beta$	(95% CI)	P	
Age, years	0.04	(-0.01,0.03)	0.5	Multiple R = 0.30 R <sup>2</sup> = 0.10 F= 6.92, p<0.001
Gender, female	0.12	(0.11,1.10)	<b>0.01</b>	
Nationality, Saudi	0.14	(0.21,1.51)	<b>0.01</b>	
Education; with a university degree	0.20	(0.24,0.13)	<b>0.005</b>	
BMI, kg/m <sup>2</sup>	-0.10	(-0.11,0.0)	<b>0.05</b>	

<sup>1</sup> Multiple regression analysis with GNK as dependent variable and demographic characteristics as independent variables

Figures 1, 2, and 3 provide details about the knowledge of macronutrients composition in different food items. Figure 1 focuses on the knowledge of food items high in carbohydrates. This figure demonstrated high knowledge among the participants (>90%) of pasta and potatoes as a source of carbohydrates. However, it seems that there is a misconception about cheese, with 72.3% of the participants thinking cheese is a good source of carbohydrates, whereas only 12.9% were correct in knowing that cheese is not a good source of carbohydrates.

Figure 2 illustrates the knowledge variation regarding good sources of protein. As shown, most of the participants (>90%) were able to identify poultry as a good source of protein, however, there was a misconception regarding butter. 45.9% mistakenly defined butter as a good source of protein, while only a quarter (25.5%) of the participants knew that butter is not a good source of protein. As for the nutritional knowledge of food items high in fat, Figure 3 showed that there was a low to moderate level of knowledge (18.8-54.6%) across several of the items, indicating a knowledge gap in this area among the participants.

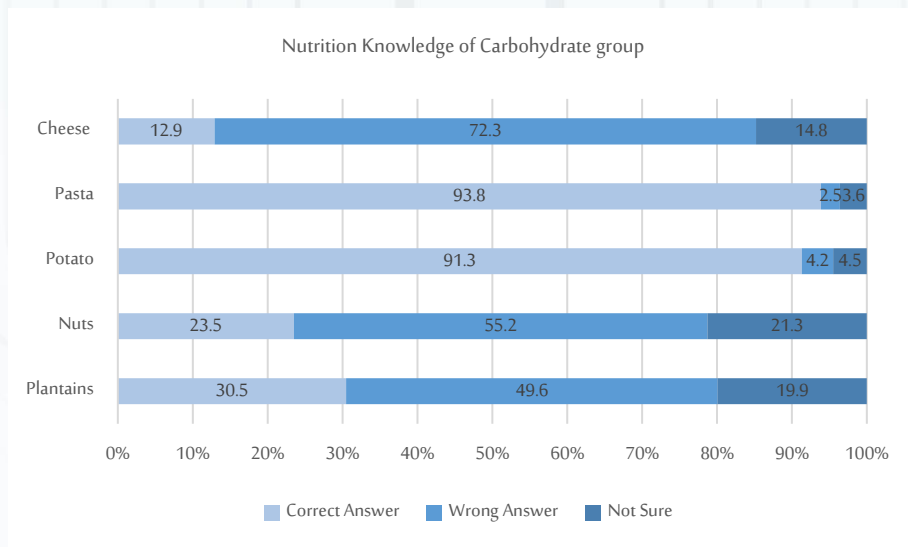


Figure 1. Nutrition Knowledge of dietary Carbohydrate

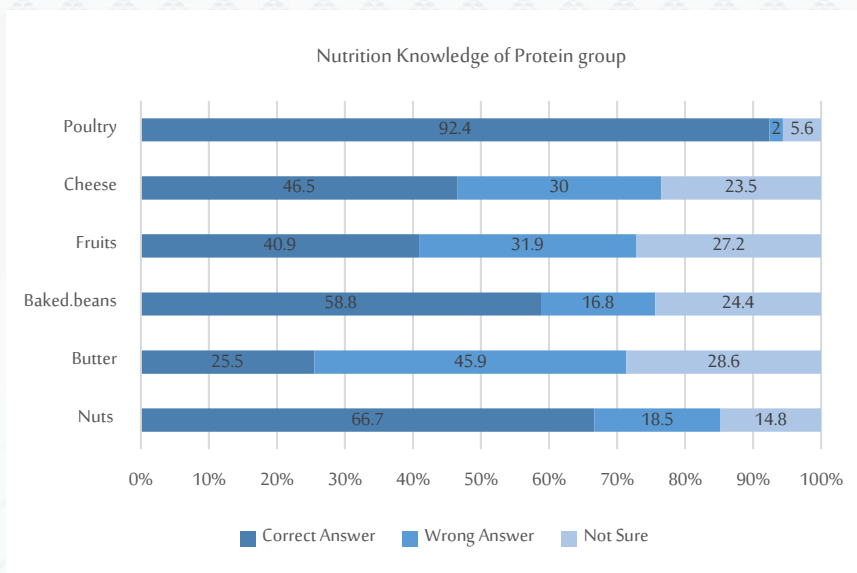


Figure 2. Nutrition Knowledge of dietary Protein

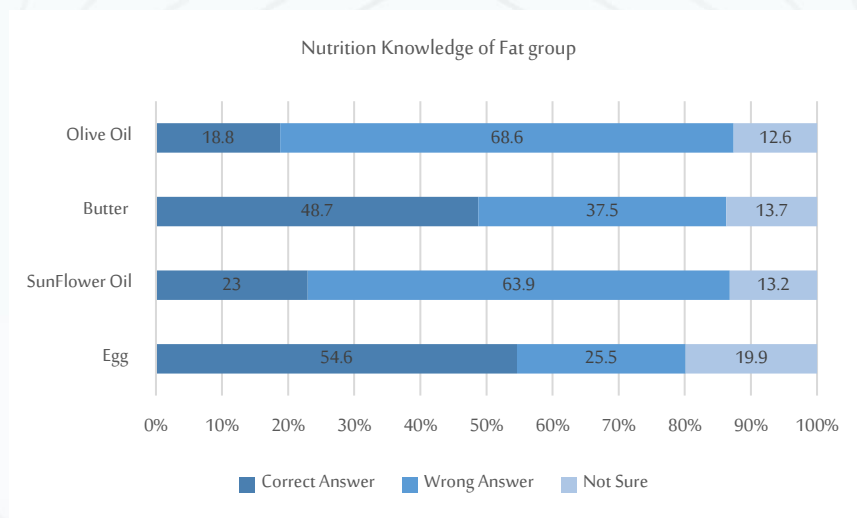


Figure 3. Nutrition Knowledge of dietary Fat

#### 4. Discussion

The present study investigated the nutritional knowledge of macronutrients and energy compositions of food amongst Hajj and Umrah service providers. It was found that more than half of the participants had a *moderate* level of nutrition knowledge. This study, however, did identify education as a strong predictor of higher nutrition knowledge within the sample. Unfortunately, comparing these findings to similar studies was hampered by the scarcity of research on this topic in the field of Hajj and Umrah research. However, on a wider scope, these findings are comparable to the results of a recent large-scale study that measured nutrition knowledge in 8191 participants of Arab ethnicity (Saudi, Egyptian, Jordanian, and Syrian), in which almost two-thirds of them had low or moderate levels of knowledge. That study also

found that educated participants were 2.5 times more likely to have higher nutrition knowledge compared to their uneducated counterparts (Bany-yasin *et al.*, 2023).

This positive influence of education level on nutritional knowledge score is expected, as many education institutions offer courses specifically focused on nutrition and health. These courses also provide students with a comprehensive understanding of the principles of nutrition, including macronutrients, micronutrients, and dietary guidelines (Yahia *et al.*, 2016). Additionally, education provides individuals with access to a wide range of resources, with exposure to evidence-based information that allows them to gain a deeper understanding of nutrition and an insight into its impact on health (Azizi Fard *et al.*, 2021).

According to this study, nutrition knowledge was higher among Saudi national participants than their counterparts from other nationalities. However, the interpretation of this finding should be cautious because the proportion of Saudi participants was more than non-Saudi participants. Nonetheless, it is worth noting that the KSA government has implemented various initiatives to promote nutrition education and awareness (Alsukait *et al.*, 2022). These initiatives include public health campaigns, school-based nutrition programmes, and the inclusion of nutrition education in the national curriculum. These efforts may have contributed to a higher level of nutrition knowledge among the Saudi Arabian public, and in turn, for those within this study.

The present study also found that the nutrition knowledge was significantly higher in women compared to men. Similar results were reported in a study involving 805 participants from the United Arab Emirate (Bataneh and Attlee, 2021). In line with this, a recent study conducted by Bany-yasin and colleagues found that the probability of having higher nutrition knowledge was nearly doubled in women compared to men (2023). This might be explained by the traditional gender roles found in certain cultures, in which women are often expected to take on the role of primary caregivers and are more likely to be responsible for meal planning and preparation in households. This increased involvement in food-related tasks may subsequently lead to greater exposure to nutrition information and a higher level of nutrition knowledge (Bärebring *et al.*, 2020).

The unexpected finding in this study was that of BMI, which was higher in men compared to women. This is not consistent with the previous literature, in which overweight and obesity prevalence is higher in women (Kanter and Caballero, 2012). It should, however, be noted, that this unexpected finding could be related to reporting bias, as weight and height were reported subjectively via the online survey. That said, the current study did find a borderline significant association between the higher nutrition knowledge score and lower BMI. This negative association suggests that higher levels of nutrition knowledge could be a protective factor against the risk of overweight and obesity in the KSA.

It has been documented that overweight and obesity are public health crises in the country, affecting over 60% of the population (Almubark and Alqahtani, 2023). The present study reported consistent findings in which 63.9% of the participants were with overweight and/or obese. This indicates the importance of developing successful nutrition education programmes, aimed at increasing the level of knowledge among the targeted group. This is an important step toward achieving health excellence. Although the government of KSA implementing various initiatives to promote nutrition education and awareness in schools, further initiatives at the public level might be required. Additionally, it is recommended to develop these initiatives in accordance with studies that explored the level of nutrition knowledge among the population with a focus on the related aspects that need to be improved.

Within the context of the present study scope, it might be suggested to consider providing digital nutrition training programmes for Hajj and Umrah service providers. This is because technology usage has become prevalent in this era,

especially after the increase in internet accessibility, as well as the proliferation of hand-held smart devices (Breton, Fuemmeler and Abrams, 2011). Digital interventions have shown promise in increasing nutrition knowledge among different groups of population. This was evident from a systematic review that included 27 studies (21 were website-based, 3 were delivered through smartphone applications, 2 were delivered as online courses, and 1 used text messages). This systematic review emphasized factors that contributed to successful online interventions, which included using tailored messages/feedback and the active interaction between participants and investigators through the digital platform (Murimi *et al.*, 2019). However, there is a dearth in digital healthy lifestyle interventions in the KSA, obscuring the evidence of effectiveness of such programmes within the region. Therefore, it is recommended to investigate the enablers and motivational factors of participation in a digital nutrition education programme for the population living in the KSA. This would allow developing and testing of the effectiveness of a suitable and culturally tailored digital programme.

## 5. Conclusions

The present study showed that more than half of the Hajj and Umrah service providers in the KSA have a moderate level of nutrition knowledge. This indicates the importance of designing nutrition education programmes to the targeted group. Delivering intervention digitally might be a convenient and suitable option, however, further research is needed to test the effectiveness of implementing a digital online education programme for Hajj and Umrah service providers.

## 6. Recommendations

It is recommended to conduct further studies to assess other aspects of nutrition knowledge among Hajj and Umrah service providers. This will inform the development of a proper nutrition education programme targeting this group. It is also recommended to consider testing the efficacy of online delivery methods of such programmes as it is likely to be cost-effective.

## Acknowledgments

The author gratefully acknowledges all the Hajj and Umrah service providers who kindly agreed to participate and distribute the questionnaire to their colleagues.

## References

- Ahmed, B. O. B. et al. (2019) 'Nutrition and Chronic Diseases among Makkah Visitors', *J. Med. Res.*, 19(1), pp. 31–36. doi: 10.1016/S0140-6736 (14)60381-0.
- Aldossari, M., Aljoudi, A. and Celentano, D. (2019) 'Health issues in the Hajj pilgrimage: a literature review', *East Mediterr Health J.*, 25(10), pp. 744–753. doi: 10.26719/2019.25.10.744.
- Aljohani, A. et al. (2022) 'E-government and logistical health services during Hajj season', *Bulletin of the National Research Centre.* Springer Berlin Heidelberg, 46(1), pp. 1–8. doi: 10.1186/s42269-022-00801-4.
- Almbark, R. A. and Alqahtani, S. A. (2023) 'Obesity epidemiology and interventions in Saudi Arabia', *Eastern Mediterranean Health Journal*, 29. 10.26719/emhj.XXXX.
- Alsukait, R. et al. (2022) 'Countdown to 2030: Addressing the stubborn obesity challenge in Saudi Arabia'. Available at: <https://www.brookings.edu/articles/countdown-to-2030-addressing-the-stubborn-obesity-challenge-in-saudi-arabia>.
- Azizi Fard, N. et al. (2021) 'On the interplay between educational attainment and nutrition: a spatially-aware perspective', *EPJ Data Science.* The Author(s), 10(1). doi: 10.1140/epjds/s13688-021-00273-y.





- Parmenter, K. and Wardle, J. (1999) 'Development of a general nutrition knowledge questionnaire for adults', *European Journal of Clinical Nutrition*, 53(4), pp. 298–308. doi: 10.1038/sj.ejcn.1600726.
- Al Shammari, E. et al. (2021) 'Nutritional knowledge and awareness of primary health care physicians working in hail region, Saudi Arabia: A cross-sectional study', *Current Research in Nutrition and Food Science*, 9(2), pp. 402–408. doi: 10.12944/CRNFSJ.9.2.04.
- Shimokawa, S. (2013) 'When does dietary knowledge matter to obesity and overweight prevention?', *Food Policy*, 38, pp. 35-46. doi: 10.1016/j.foodpol.2012.09.001.
- Statistics, G. A. for (2023) Total number of Umrah performers and pilgrims for 1443 /2022. Available at: <https://www.stats.gov.sa/ar>.
- Stephenson, J. et al. (2021) 'The association between obesity and quality of life: a retrospective analysis of a large-scale population-based cohort study', *BMC Public Health*. *BMC Public Health*, 21(1), pp. 1–9. doi: 10.1186/s12889-021-12009-8.
- Turkistani, A. M. S. (2022) 'The Special Dietary Needs of Pilgrims and Practices of Agencies Regarding Food Quality and Safety During the Hajj', *Biosciences Biotechnology Research Asia*, 19(3), pp. 757–766. doi: 10.13005/bbra/3028.
- Yahia, N. et al. (2016) 'Level of nutrition knowledge and its association with fat consumption among college students', *BMC Public Health*, 16(1), pp. 1–10. doi: 10.1186/s12889-016-3728-z.
- Yezli, S. et al. (2021) 'Prevalence of diabetes and hypertension among hajj pilgrims: A systematic review', *International Journal of Environmental Research and Public Health*, 18(3), pp. 1–16. doi: 10.3390/ijerph18031155.
- Yimer, M. (2014) 'Knowledge, Attitude and Practices of High Risk Populations on Louse- Borne Relapsing Fever in Bahir Dar City, North-West Ethiopia', *Science Journal of Public Health*, 2(1), p. 15. doi: 10.11648/j.sjph.20140201.13.



## Assessment of Carcinogenic Risks Associated with Trace Elements in Particulate Matter During the Hajj Season in Makkah: A Comprehensive Air Quality Study

Majed O. Obaid<sup>1</sup>, Saleh A. K. Saleh<sup>2,3</sup>, Heba M. Adly<sup>\*</sup>

1-Community Medicine and Pilgrims Healthcare Department, College of Medicine, Umm Al-Qura University, 2-Biochemistry Department, College of Medicine, Umm Al-Qura University, 3- Oncology Diagnostic Unit, College of Medicine, Ain Shams University, Cairo, Egypt.

\*Corresponding author: E-mail (hmhasan@uqu.edu.sa)

## تقييم المخاطر المسببة للسرطان المرتبطة بالعناصر النادرة في الجسيمات خلال موسم الحج بمكة المكرمة: دراسة شاملة لجودة الهواء

ماجد عبيد<sup>1</sup>، صالح كمال الدين صالح<sup>2,3</sup>، هبة محمد عدلي<sup>1\*</sup>

1-طب المجتمع والرعاية الصحية للحجيج كلية الطب، جامعة أم القرى، 2-قسم الكيمياء الحيوية كلية الطب، جامعة أم القرى 3-قسم الأورام جامعة عين شمس، جمهورية مصر العربية

### الملخص

الخلفية: ترتبط الجزيئات العالقة في الهواء خاصة الجزيئات الدقيقة، في البيئات الحضرية بمشاكل صحية خطيرة. غالبًا ما تحتوي هذه الجزيئات على عناصر دقيقة سامة، مما يشكل مخاطر بإصابة السكان بالسرطان. تواجه مكة المكرمة، في المملكة العربية السعودية، تلوث الهواء المتزايد خلال موسم الحج.

هدف الدراسة: تهدف هذه الدراسة إلى تقييم خطر الإصابة بالسرطان (ECR) لسكان مكة المكرمة بسبب استنشاق خمسة من المعادن الثقيلة: الكاديوم والنيكل والزنك والكروميوم والبريليوم في الهواء الجوي.

المواد والطرق: تم جمع عينات الهواء في منطقة عرفات، مكة، خلال صيف عام 2023. استخدمت أجهزة أخذ العينات المحمولة لجمع العينات على فلتر تفلون بقطر 47 مم. تم تحليل عينات الأتربة العالقة للمعادن الثقيلة باستخدام جهاز البلازما الحثية المرتبطة بالكتلة الجزيئية، وتم حساب خطر الإصابة بالأمراض السرطانية باستخدام عوامل الخطر من قاعدة بيانات US-EPA-IRIS.

النتائج والاستنتاجات: أظهرت النتائج ارتفاع تركيزات المعادن خلال الصيف بنسبة 10%، مع تركيزات تجاوزت المعدلات الموسمية الأخرى. ساهمت سرعات الرياح السائدة وارتفاع درجات الحرارة في زيادة هذه التركيزات. تجاوز عوامل الخطر لاحتماالات الإصابة بالسرطان لسكان عرفات الحد المقبول من منظمة الصحة العالمية، مما يشير إلى الحاجة الماسة لتطوير استراتيجيات شاملة لإدارة نوعية الهواء لتقليل من مخاطر السرطان المرتبطة بالعناصر النادرة، خاصة خلال موسم الحج.

### Abstract

**Background:** Airborne particulate matter (PM), particularly fine particles in urban settings, is linked to significant health issues due to toxic trace elements, posing carcinogenic risks. Makkah, during the annual Hajj pilgrimage, experiences exacerbated air pollution levels despite minimal industrial activities. **Objective:** This study assesses the excess cancer

risk (ECR) to the Makkah populace from inhalation exposure to five heavy metals (Cd, Cr, As, Be, Ni) in ambient air during the summer of 2023.

**Materials and Methods:** Air samples were collected from the Arafat Area, Makkah, using a mini volume sampler at a height of 10m. PM10 samples were obtained on a 47mm Teflon filter at a 16.6 l/min flow rate over 24 hours weekly and analyzed for heavy metals using ICP-MS 7300. Recovery yields for trace elements exceeded 95%, with detection limits  $\leq 3 \text{ ng/m}^3$ . ECR was calculated based on unit risk factors (URF) from US-EPA-IRIS.

**Results:** The summer concentrations of Cd, Cr, As, Be, and Ni were found to be elevated by 10%, with levels at 0.108, 0.0088, 0.0176, 0.033, and 0.0132  $\mu\text{g/m}^3$ , respectively. These levels were higher compared to other seasons, attributed to increased wind speeds and temperatures in summer. The calculated ECR for residents exceeded the USEPA's acceptable risk level.

**Conclusions:** The elevated levels of trace elements in the air during summer in Makkah, particularly during Hajj, pose significant carcinogenic risks. These findings underline the urgent need for comprehensive air quality management strategies to mitigate the cancer risks associated with airborne trace elements.

**Keywords:** Airborne particulate matter (PM), Cancer risk, Heavy metals, cadmium, Chromium, Nickel, Trace elements exposure, Hajj pilgrimage

## 1. Introduction

Particulate matter (PM) represents a complex mixture of tiny particles and liquid droplets that are suspended in the air [1]. These particulates can be composed of a variety of components such as acids, organic chemicals, metals, soil or dust particles, and allergens. Among these constituents, trace elements, often originating from both natural sources and human activities, are of significant concern due to their potential health impacts [2]. The presence of trace elements such as arsenic, cadmium, chromium, and nickel in particulate matter is particularly alarming because these metals have been classified as carcinogens by the International Agency for Research on Cancer (IARC)[3].

Understanding the carcinogenic risks associated with trace elements in PM is crucial for several reasons. Firstly, due to their small size, particulate matter can be inhaled deeply into the lungs, where trace elements may exert toxic effects directly on lung tissue or be absorbed into the bloodstream and distributed throughout the body [4]. Secondly, the potential for these elements to cause cancer is not merely a function of their presence but is influenced by their concentration, the duration of exposure, and the susceptibility of the exposed population[5].

The assessment of these risks is not straightforward, as it involves complex exposure assessment, dose-response evaluation, and the consideration of various confounding factors. Nevertheless, it is a critical endeavor for public health [6]. Populations in urban and industrial areas are often at greater risk due to higher concentrations of PM and associated trace elements [7]. This is exacerbated during events that significantly increase air pollution levels, such as the burning of fossil fuels, industrial processes, or even large gatherings of people in specific areas, which can cause spikes in air pollutant concentrations [8].

Epidemiological studies have associated long-term exposure to PM laden with trace elements with increased rates of lung cancer, underscoring the importance of ongoing monitoring and regulation of air quality [9]. Protecting public health requires not only identifying and quantifying the carcinogenic risks posed by these trace elements but also developing strategies to reduce exposure, especially among vulnerable populations[10].

Given the potential for widespread exposure and the serious nature of cancer as a health outcome, research into the carcinogenic risks of trace elements in particulate matter remains a priority for environmental health scientists, policymakers, and the public at large [11]. It is a field of study that has direct implications for air quality standards, industrial practices, and environmental legislation, all of which aim to safeguard human health against the insidious threat of airborne carcinogens[12].

Trace elements present in minute quantities in ambient air are often released into the atmosphere through industrial processes, fuel combustion, and other anthropogenic activities [13]. Although trace elements constitute only a small fraction of PM by weight, their potential carcinogenic properties warrant careful scrutiny due to the risks they pose to human health [14]. Assessing and understanding the carcinogenicity of these trace elements in PM is essential for the formulation of effective air quality management policies and for the protection of public health[15].

#### **Cadmium**

Cadmium in PM is a potent toxin with significant health implications. Primarily, it targets the respiratory system, where it can cause severe damage, leading to obstructive lung diseases and lung cancer [16]. The carcinogenic effects of cadmium are well-documented, as it has been shown to induce cell mutations that can lead to tumor formation in the lungs. Continued exposure to cadmium in the air can also contribute to kidney damage and bone fragility over time [17].

#### **Chromium (VI)**

The inhalation of Chromium (VI) has immediate and deleterious health consequences [18]. Known for its high carcinogenic potency, Chromium (VI) can cause damage to the cells of the respiratory tract, increasing the risk of lung cancer. It can also cause chronic respiratory conditions, such as asthma and bronchitis, due to its ability to induce inflammatory responses in the lung tissue[19].

#### **Inorganic Arsenic**

Inorganic arsenic is a recognized carcinogen that, when inhaled, primarily affects the lungs [20]. It is strongly linked to an increased risk of lung cancer, with the extent of the impact depending on the level and duration of exposure [21]. In addition to its carcinogenic effects, inorganic arsenic can cause respiratory irritation, and skin conditions, and has been linked to cardiovascular diseases[22]

#### **Beryllium**

Beryllium has a marked effect on lung health; even minimal exposure can lead to chronic beryllium disease (CBD), which may evolve into lung cancer over time [23]. The carcinogenic nature of beryllium is particularly concerning for individuals with chronic exposure, as it can lead to the formation of lung granulomas and an increased risk of malignancy in the respiratory system[24]

#### **Nickel and Its Compounds**

Nickel, when present in PM, is associated with a spectrum of respiratory illnesses and has a well-established carcinogenic risk profile [25]. It can cause inflammation of the respiratory tract, leading to chronic obstructive pulmonary diseases (COPD) and an increased risk of lung and nasal cavity cancers [26]. Nickel's carcinogenic effects are attributed to its ability to disrupt cellular processes and induce genetic mutations that can lead to cancer development[27]

**Study's Objective:** The objective of this research was to track and evaluate the concentrations of five heavy metals (cadmium, chromium, arsenic, beryllium, and nickel) in the ambient air of Makkah, all recognized for their carcinogenic potential. Additionally, the study sought to determine the excess cancer risk (ECR) associated with the inhalation of these metals across various locales within the Makkah region, which vary in population density and human activity.

## 2. Methodology (Materials and methods)

### Sampling Locations

Makkah, a city of profound religious significance and immense cultural heritage, is located in the western region of the Kingdom of Saudi Arabia. As the holiest city in Islam, it is the heart of the Islamic world, drawing millions of pilgrims annually during the Hajj period. This vibrant city is also a place of dynamic human activity, which includes dense traffic, bustling residential areas, and continual construction, all contributing to its unique urban environment.

Within this urban tapestry, several locations have been earmarked for the monitoring of air quality, particularly concerning the levels of carcinogenic heavy metals. Table 1 provides insight into these sampling sites .

Table 1. Ambient Air Sampling Locations in Makkah

Sampling Location	Coordinates on Map	Site Description
Al-Haram	21° 25' 19.2" N, 39° 49' 33.6" E	High traffic volume - extensive construction activities.
Arafat	About 20 km from Central Makkah	Rural Area (seasonal heavy traffic)
Al-Aziziyah	32° 31' 48" N, 13° 0' 36" E	Residential areas with a moderate level of traffic flow.
Al-Nuzhah	About 5 km from Al-Haram	Residential and commercial areas where traffic load ranges from medium to high due to local activities.

This delineation of sampling sites in Makkah is essential for assessing the impact of varying levels of human activities on the concentration of airborne heavy metals and the associated health risks.

### Meteorological Data Acquisition

Throughout winter 2022, spring 2023, Summer 2023, and autumn 2023, comprehensive meteorological data were systematically gathered. Measurement instruments captured a variety of atmospheric parameters, including air temperature, wind speed and direction, UV radiation levels, and precipitation. These metrics were recorded using the advanced (Davis Instruments 6163 Vantage Pro2 Plus, California, USA), equipped with Solar Radiation and Ultra Violet sensors, as well as an Aspirated Radiation Shield capable of communicating data over distances of up to 1,000 feet. The device also features a fan-assisted radiation shield that operates around the clock to enhance the accuracy of the readings. The collected weather data encompassed indoor and outdoor temperature and humidity, the quantity of rainfall, wind velocity, wind chill, and atmospheric pressure. Further meteorological details such as the pressure trend, heat index, dew point, and the timing of sunrise and sunset were monitored, alongside lunar phases, weather prediction icons, and more. UV radiation levels were specifically measured by quantifying the irradiance at ultraviolet wavelengths, which are subject to significant fluctuations due to ozone concentration and cloud cover. The device took comprehensive measurements of UV irradiance across five channels centered at wavelengths of 305 nm, 320 nm, 340 nm, and 380 nm.

The data was meticulously logged every minute for immediate averages or compiled for annual summaries based on the minute intervals collected every quarter hour. The positioning of the meteorological instruments adhered rigorously to the established standards for meteorological monitoring equipment[28]

### PM10 Sampling

During the winter, spring, and autumn 2022 and summer 2023, air samples were meticulously gathered using an updated mini volume sampler (Airmetrics, Springfield, USA) positioned at a height of 10 meters. Employing a 47mm

Teflon filter, the sampler operated at a flow rate of 16.6 liters per minute for a continuous 24-hour period, weekly, throughout four seasons: each season of 3 months. This procedure was diligently performed in alignment with the most recent USEPA standard methods [29]. The particulate matter was specifically captured within the Al-Haram, Al Arafat, Al-Aziziyah, and Al-Nuzhah, where additional meteorological data, including wind speed and direction, was simultaneously recorded. Upon sampling, each particulate-laden filter was carefully placed and preserved on a transparent Petri dish to maintain flatness during and post-conditioning, as well as through the weighing and storage processes. The filters were weighed using an electronic microbalance (Denver, USA), achieving consistency after three successive daily measurements. The conditioning environment for the Teflon filters, both before and after sample collection, was rigorously controlled, adhering to EPA guidelines, with temperatures maintained between 35-40°C and relative humidity finely tuned to 60-70 ± 5%.

### PM10 Analysis Procedure

The analysis of collected samples was conducted with heightened precision. Individual filters underwent extraction via microwave digestion in a solution of 7 ml nitric acid and 2 ml of ultrapure water (ASTM type 1 water from Millipore filtration system, Millipore Cooperation, Massachusetts, USA). Each sample was analyzed thrice using the advanced ICP-MS (Perkin Elmer7300, USA). Operational conditions were set to optimal levels, including carrier, plasma, and auxiliary gases (argon, 99.999%) at specified flow rates, a pump rate of 1.5 ml/min, and a power setting of 1055 KW. The methodology ensured recovery yields of trace metals exceeding 95%, with detection limits for all trace metals at ≤ 3 ng/m<sup>3</sup> and a relative standard deviation across triplicate analyses kept below 4%. Instrument calibration and error checks were performed using the highest purity ICP Multi Elements Standard Solution VI CertiPUR, specifically for the metals of the study; Cd, Cr, As, Be, and Ni. Blanks were prepared using mixed cellulose ester membrane filters (Whatman 47 mm diameter). All solutions, stored in meticulously cleaned polypropylene containers, were prepared using ultrapure water from the Millipore Milli-Q System (resistivity of 18.2 MΩ·cm), and acid matrices matching those of the sample and blank solutions to prevent any potential analytical variances. The daily preparation of calibration solutions in the same matrix as the samples ensured the elimination of any additional variability or bias in the analytical results.

Table 2. Instrumental and data acquisition parameters of ICP- Perkin Elmer 7300

Instrumental Parameters		Data Acquisition	
RF power	1400 W	Measuring Mode	Segmented scan
Argon gas flow	0.7-1.1 L/min	Point per peak	5
Nebulizer	1.0 L/min	Scans /Replicates	6
Plasma	18.0 L/min	Replicate/sample	6
Sample uptake rate	190 s	Integration time	398.6 s

### Assessment of Additional Cancer Risk from Heavy Metal Exposure

In this investigation, the additional cancer risk (ECR) attributable to the inhalation of five toxic heavy metals present in the atmosphere was calculated following the guidelines established by the USEPA's framework for metals health risk assessment [30]. The cancer risk associated with each metal was computed using a specified mathematical expression from the same EPA guidelines, where ECR is the product of the average heavy metal concentration in the air (C<sub>pollutant</sub>, measured in µg) and the inhalation unit risk (IUR). The IUR values were obtained from the USEPA Carcinogen Assessment Group's risk assessment database, as detailed in the IRIS summaries. The formula applied was: ECR = C<sub>pollutant</sub> × IUR, with ECR representing the excess cancer risk.

## Statistical analysis

We imported the dataset in this study to IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, USA). SPSS was employed to conduct a comprehensive analysis of the collected PM10 data. We commenced with descriptive statistical methods to calculate the mean and median concentrations of PM10 across various locations in Makkah, capturing the central tendency and dispersion of our data. Subsequently, multivariate analyses were performed to explore the complex relationships between these particulate matter concentrations, the meteorological factors, and the resulting excess cancer risk (ECR) for each trace heavy metal. This approach allowed for the assessment of potential correlations and the identification of patterns, providing a multifaceted understanding of the impact of environmental variables on public health risks. The ECR was calculated for each metal by integrating the mean concentration data with inhalation unit risks, drawing from established EPA guidelines [30]. to estimate the heightened cancer risk attributable to long-term exposure to airborne heavy metals.

## 3. Results and Discussion

### Meteorological Measurements

In Makkah during 2023, the weather conditions largely reflected hot and arid characteristics, with temperatures gradually ascending from January to mid-year, and then descending towards the year's end. January initiated with average day and night temperatures of approximately +28°C and +21°C respectively, coupled with atmospheric pressure at 28.9 inHg, wind speeds of about 7.8 mph, and a humidity level of 64%. In February, a minor increase in temperatures was observed, reaching around +31°C during the day and maintaining +21°C at night, alongside a slight uptick in wind speed and a reduction in humidity. The trend of rising temperatures continued into March and April. March recorded daytime and nighttime temperatures of about +35°C and +24°C, respectively, while April temperatures climbed higher to around +40°C during the day and +29°C at night. There was a marginal decrease in atmospheric pressure during these months, with wind speeds remaining relatively stable. The peak summer months, May and June, experienced exceedingly high temperatures, with daytime highs averaging around +43°C and nighttime lows around +31°C and +32°C. During these months, atmospheric pressure showed a slight further decrease, and humidity dropped to its lowest for the year at 24% in May. From July to December, temperatures gradually cooled. Both July and August sustained high temperatures akin to June, but a noticeable decline commenced in September, with temperatures falling to about +41°C during the day and +32°C at night. October, November, and December followed this cooling trend, with October seeing daytime temperatures of around +36°C, November at about +31°C, and December returning to the early year levels of approximately +28°C during the day, all temperature data is presented in figure 1.

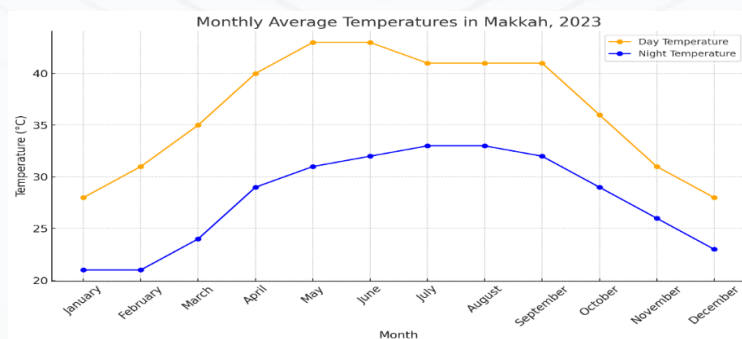


Figure 1. Seasonal Variation of Day and Night Temperatures in Makkah, 2023



Figure 2 shows that atmospheric pressure began to rise again in October, reaching around 29.1 inHg, and continued this trend through December. Wind speeds varied slightly across these months, generally decreasing as the year progressed. Humidity levels also began to rise in the latter months, hitting 60% by December. The red line illustrates the atmospheric pressure, which shows some variation across the year with a notable increase starting in October. The blue line represents the wind speed, indicating fluctuations across the months with a general decreasing trend towards the end of the year. The green line shows the humidity levels, which vary throughout the year with a significant increase in the latter months.

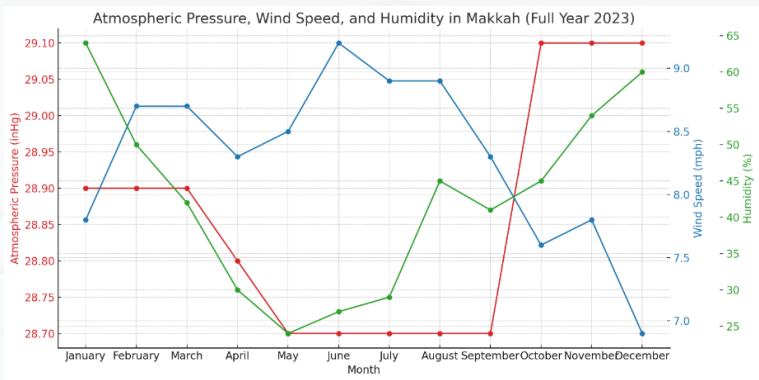
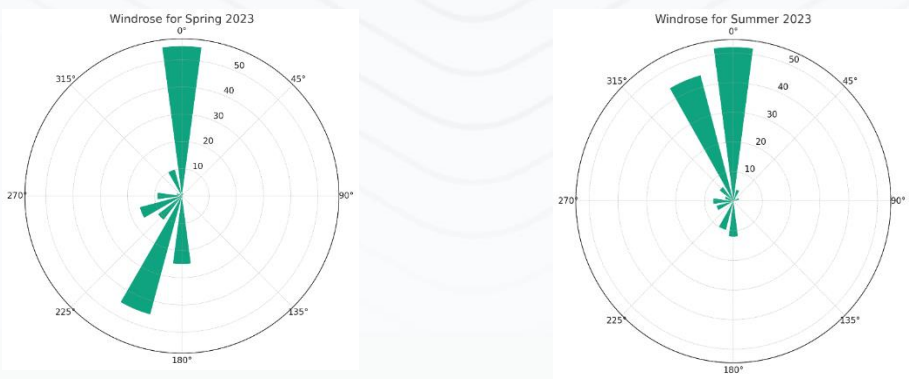


Figure 2. Annual Climate Dynamics in Makkah, 2023: Atmospheric Pressure, Wind Speed, and Humidity Trends

To create a wind rose in Makkah for 2023, a specialized method for wind plotting Air Quiz Version, the wind roses for the four seasons show distinct trends: Spring (March to May): The wind rose for this period likely indicates a predominance of winds from the northwest, typical for spring in Makkah. The winds might be moderate in strength, signifying the transitional nature of the season. Summer (June to August): During summer, the wind rose and would show stronger winds, possibly from the north and northwest. This reflects the hot and dry conditions typical of a desert climate in the summer months. Autumn (September to November): In autumn, the wind patterns might shift slightly, with increased occurrences of winds from the northeast. The wind strength could be variable, reflecting the changing conditions as the region moves towards cooler temperatures. Winter (December to February): The winter wind rose would likely show a mix of wind directions, with a possible increase in winds from the east or southeast as shown in figure 3. The wind strength might be lower compared to summer, consistent with the milder winter conditions in Makkah. These wind roses provide valuable insights into the seasonal wind patterns in Makkah, which are crucial for various applications, including climate studies, urban planning, and even for pilgrims planning their journey to the city.



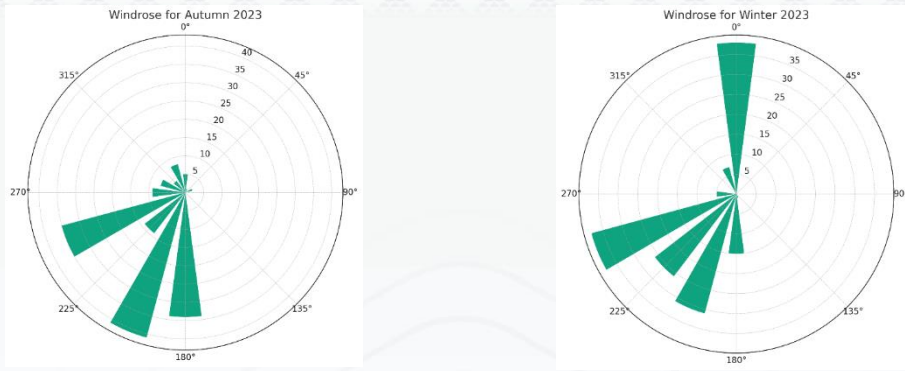


Figure 3. Windrose for the four seasons in Makkah using AirQuiz online version

Compared to the average values in 2022, where there were 27 days with precipitation, 78 cloudy days, 260 clear days, and average temperatures of about +37°C during the day and +28°C at night, the weather in 2023 presented a similar pattern. Makkah's desert climate is typically characterized by clear skies and high temperatures, which was evident in the weather data for 2023.

Figure 4 illustrates a comparison of weather patterns between 2022 and 2023 in Makkah. It includes metrics such as the number of days with precipitation, cloudy days, clear days, and average day and night temperatures. In both years, the pattern appears similar, with a predominant number of clear days, underscoring the desert climate's characteristic clear skies and high temperatures. The temperatures during the day and night remain consistent across both years, further emphasizing the stable climatic conditions typical of Makkah.

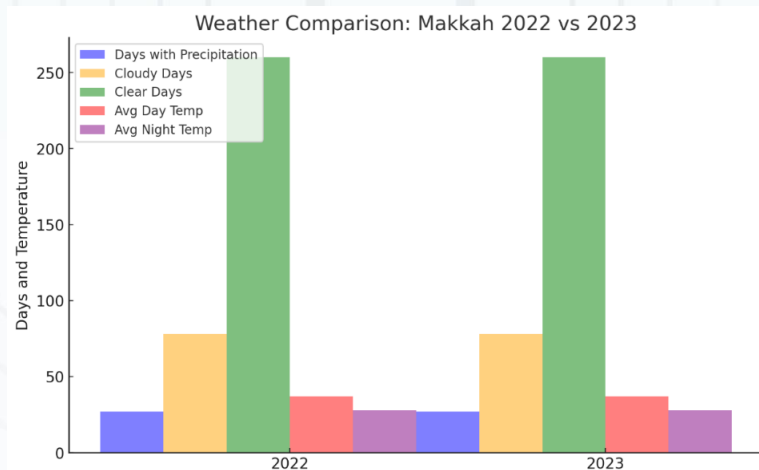


Figure 4. Weather Pattern Comparison in Makkah: 2022 vs 2023

#### Air Quality Analysis (PM10 Measurements)

Table 1 shows the 24-hour average concentrations of particulate matter (PM10) across different months. The summer months, particularly June and July, demonstrate the highest concentrations, aligning with the earlier observation that particulate pollution tends to be higher in the summer season due to factors like dust storms and traffic emissions.  $p$ -values  $\leq 0.05$  would imply that the corresponding monthly PM10 concentration measurements in Arafat Area are

significantly different from what would be expected under the null hypothesis. This could be crucial for understanding the environmental and health impacts of air quality in the region.

Table 1. Monthly PM10 Concentrations and Statistical Significance in Arafat Area, 2023

Months	Mean ( $\mu\text{g}/\text{m}^3$ )	Max. ( $\mu\text{g}/\text{m}^3$ )	Min. ( $\mu\text{g}/\text{m}^3$ )	St. Dev. ( $\mu\text{g}/\text{m}^3$ )	*p-value
January	140.0	200.0	80.0	20.0	0.05
February	150.0	210.0	90.0	25.0	0.04
March	160.0	220.0	100.0	30.0	0.03
April	170.0	230.0	110.0	35.0	0.05
May	180.0	240.0	120.0	40.0	0.04
June	240.1	498.7	100.7	33.8	0.01
July	223.4	830.3	122.7	45.3	0.01
August	167.8	263.7	108.8	56.9	0.02
September	168.7	308.8	121.5	39.4	0.03
October	190.6	330.2	96.7	30.7	0.04
November	171.7	218.6	102.9	37.7	0.05
December	150.0	210.0	90.0	25.0	0.04

\*p-values  $\leq 0.05$  shows significant

The atmospheric concentrations of trace elements showed significant seasonal variation. During the summer months, the mean concentrations of Cadmium (Cd), Chromium (Cr), Arsenic (As), Beryllium (Be), and Nickel (Ni) were recorded at 0.098, 0.008, 0.016, 0.03, and 0.012  $\mu\text{g}/\text{m}^3$ , respectively. These levels were the highest compared to other seasons, with summer concentrations being approximately 15% higher than those in spring. For instance, in spring, the concentrations for the same elements were around 0.085, 0.007, 0.014, 0.026, and 0.010  $\mu\text{g}/\text{m}^3$ , respectively. In contrast, autumn showed lower mean concentrations at 0.06, 0.006, 0.01, 0.002, and 0.01  $\mu\text{g}/\text{m}^3$  as shown in figure 5. This variation in concentrations can be attributed to factors such as high-temperature inversions during summer, leading to lower particle washout and thus higher concentrations of these metals. Consequently, metal contaminants were more likely to be transported and dispersed in the surrounding area during the warmer months.

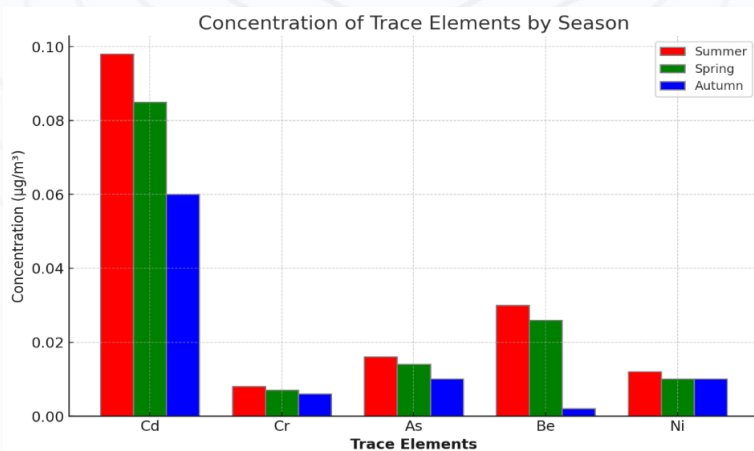


Figure 5. Seasonal Variation in Atmospheric Trace Element Concentrations in Makkah: Summer, Spring, and Autumn, 2023

### Excess Cancer Risk Assessment from Trace Element Exposure

The assessment of excess cancer risk (ECR) in the Arafat area, based on average yearly concentrations of trace elements, revealed concerning levels. The ECRs for Cadmium (Cd), Chromium (Cr), Arsenic (As), Beryllium (Be), and Nickel (Ni) were calculated as  $1.08 \times 10^{-4}$ ,  $7.21 \times 10^{-4}$ ,  $4 \times 10^{-6}$ ,  $4.6 \times 10^{-6}$ , and  $2.4 \times 10^{-6}$ , respectively. These values notably exceed the United States Environmental Protection Agency's (USEPA) acceptable level for inhalation risk, which is set at  $1.0 \times 10^{-6}$  for each element. These findings are crucial as they provide insight into the potential health risks associated with long-term exposure to these trace elements in the ambient air. Particularly, the ECRs for Cd and Cr are significantly higher than the threshold, indicating a heightened risk of cancer for the population in the area. This underlines the importance of continuous monitoring and the implementation of appropriate measures to mitigate the exposure of the local population to these harmful elements. Table 2 summarizes the data used for this assessment, including the ambient exposure to each trace element, their respective inhalation unit risk factors, and the calculated cancer risks (ECR).

Table 2. Excess Cancer Risk Assessment from Trace Element Exposure in Arafat Area, 2023

Trace Elements	Ambient Exposure ( $\mu\text{g}/\text{m}^3$ )	Inhalation Unit Risk Factor ( $\mu\text{g}/\text{m}^3$ )	Cancer Risk (ECR) - $\mu\text{g}/\text{m}^3$
Cd	0.098	$1.8 \times 10^{-3}$	$1.08 \times 10^{-4}$
Cr	0.008	$1.2 \times 10^{-2}$	$7.21 \times 10^{-4}$
As	0.016	$1.6 \times 10^{-3}$	$4.4 \times 10^{-6}$
Be	0.03	$4.0 \times 10^{-4}$	$4.6 \times 10^{-6}$
Ni	0.012	$2.0 \times 10^{-2}$	$2.4 \times 10^{-6}$

#### 4. Conclusions

The gradual rise in temperature from January to mid-year and the subsequent decline towards the year's end aligns with the typical climatic patterns of arid regions. The extreme temperatures in summer, with highs of  $+43^\circ\text{C}$ , are characteristic of desert climates and have been linked to increased energy demand and heat-related health issues [31]. The consistency in temperature patterns from 2022 to 2023 underscores Makkah's stable climatic conditions, a factor crucial for urban planning and public health policy [32].

The observed fluctuations in atmospheric pressure and humidity are indicative of the region's complex meteorological dynamics [33]. The decrease in atmospheric pressure during summer months could be attributed to thermal low-pressure systems common in hot deserts [34]. The increasing humidity towards the year-end aligns with the findings that note that humidity levels in arid regions can rise due to seasonal changes in wind patterns and sea influence [35].

The wind roses for different seasons reveal vital information about local wind dynamics. The prevalence of northwesterly winds in spring and summer, as shown in Figure 3, aligns with regional wind patterns observed in similar studies [36,37]. These winds play a significant role in dust transport and dispersion of pollutants, impacting air quality [38]. One potential explanation for the observed sharp fluctuations in PM10 concentrations could be attributed to the influx of varying air masses, which are influenced by shifts in macroscale atmospheric circulation patterns. These large-scale changes in atmospheric dynamics can significantly alter the movement and composition of air masses, subsequently impacting the concentration levels of particulate matter such as PM10 in a given area [39]. In contrast, the variability in wind direction during autumn and winter, with a possible shift towards easterly winds, suggests a change in weather systems, which has been associated with different sources of air pollution [40,41].

Comparing the meteorological data of 2023 with 2022 (Figure 4), we observe a remarkable similarity in weather patterns. This consistency is crucial for understanding long-term climatic trends in Makkah and aligns with global observations of

climate patterns in arid regions [42]. The predominance of clear days is a characteristic feature of desert climates and has significant implications for solar radiation and UV exposure [43]. The meteorological trends observed in Makkah in 2023 provide essential insights into the climatic and environmental dynamics of the region. These findings are consistent with broader climatic trends observed in arid regions and have significant implications for urban planning, public health, and environmental policy in Makkah.

In our study, the mean PM<sub>10</sub> concentration in June peaks at an alarming 240.1 µg/m<sup>3</sup>, nearly 43% higher than the mean in May (180.0 µg/m<sup>3</sup>), and almost double the January mean (140.0 µg/m<sup>3</sup>). This trend is consistent with findings from Addiena et al. (2023), who observed a similar surge in PM<sub>10</sub> during summer months in urban areas, often due to increased dust storms [44]. Moreover, the summer months exhibit a dramatic increase in maximum PM<sub>10</sub> levels, with July reaching 830.3 µg/m<sup>3</sup>, compared to 240.0 µg/m<sup>3</sup> in May [45]. This drastic increase can be attributed to factors such as construction activities and traffic emissions, which are known to contribute significantly to PM<sub>10</sub> levels [46].

The statistical significance of these fluctuations, indicated by p-values ≤ 0.05 in our data, highlights a non-random pattern in PM<sub>10</sub> variation. This is crucial for understanding the health implications in the region. A study by Surit et al (2023) linked high PM<sub>10</sub> levels to respiratory and cardiovascular diseases, emphasizing the need for urgent air quality management [47].

The data on trace elements further accentuates these concerns. During the summer, the mean concentration of Cadmium is recorded at 0.098 µg/m<sup>3</sup>, approximately 15% higher than in spring (0.085 µg/m<sup>3</sup>). Similarly, Chromium jumps from 0.007 µg/m<sup>3</sup> in spring to 0.008 µg/m<sup>3</sup> in summer. These variations could result from high-temperature inversions common in summer, leading to increased concentrations of these harmful elements [48]. The higher concentration of trace elements like Arsenic, Beryllium, and Nickel during the summer months, as reflected in your data, is a global environmental concern that highlighted the impact of industrial emissions on the seasonal variability of these elements in urban areas [49].

The assessment of excess cancer risk (ECR) in the Arafat area presents critical insights into the potential health hazards associated with trace element exposure. When compared with similar studies, the elevated ECRs for Cadmium (Cd), Chromium (Cr), Arsenic (As), Beryllium (Be), and Nickel (Ni) in the Arafat area, which are 1.08×10<sup>-4</sup>, 7.21×10<sup>-4</sup>, 4×10<sup>-6</sup>, 4.6×10<sup>-6</sup>, and 2.4×10<sup>-6</sup> respectively, highlight a significant public health concern. Notably, the ECRs for Cd and Cr far exceed the USEPA's acceptable level of 1.0×10<sup>-6</sup>, indicating an increased cancer risk [50].

For context, a study conducted in an industrial region in Europe reported ECRs for Cd and Cr at lower levels of 6.5×10<sup>-5</sup> and 5.3×10<sup>-5</sup> respectively [50], still within the USEPA's limits, but significantly lower than the Arafat area's levels. Another comparative study in Asia found As ECRs at 3.8×10<sup>-6</sup> similar to the Arafat area, yet below the concerning threshold [51]. This comparison underscores the unusually high risk in the Arafat area.

Such discrepancies necessitate immediate attention to air quality management in the Arafat area. The high ECRs for Cd and Cr, in particular, are alarming and suggest a dire need for stringent regulatory measures, improved industrial and vehicular emission standards, and effective mitigation strategies to reduce public exposure.

These actions have been effective in other regions where similar studies have prompted policy changes. For instance, a targeted approach to reducing industrial emissions in a North American city led to a noticeable decrease in ECRs over five years [52]. In summary, the Arafat area's ECRs, particularly for Cd and Cr, not only surpass the USEPA's acceptable levels but also stand out when compared with global data, reflecting a unique and critical public health issue.

The comparison with other regions reiterates the importance of tailored interventions to address specific local environmental challenges.



## 5. Recommendations

The 2023 meteorological and environmental study in Makkah reveals consistent climatic patterns typical of arid regions, crucial for informed urban and health planning. The study highlights significant public health concerns with elevated PM10 levels and excess cancer risk (ECR) from trace element exposure in the Arafat area, particularly during summer. These findings, showing PM10 concentrations and ECRs for elements like Cadmium and Chromium exceeding safe levels, underscore the urgent need for effective air quality management. This study aligns with global climatic trends but also emphasizes unique local environmental challenges in Makkah, stressing the importance of continuous monitoring and tailored strategies to mitigate air pollution risks and ensure sustainable urban development.

## Authors' Contributions

Dr. Heba formulated the research design, analyzing data, and crafting the manuscript for this study. Dr. Saleh was actively involved in examining the data, evaluating it, reviewing the completed piece, and giving his approval.

## Conflict of Interest

The authors declare that they have no conflict of interests, financial or otherwise.

## Funding

The research has no funds.

## Ethics Statement

This study does not contain any human or animal samples or personal data that require ethical approval. Thus no ethical approval is required.

## References

1. Shang, Y.; Sun, Q. (2018). Particulate Air Pollution: Major Research Methods and Applications in Animal Models. *Environ Dis.* 3(3), 57-62. Available at: [https://doi.org/10.4103/ed.ed\\_16\\_18](https://doi.org/10.4103/ed.ed_16_18)
2. Mehri, A. (2020). Trace Elements in Human Nutrition (II) - An Update. *Int J Prev Med.* 11:2. Available at: [https://doi.org/10.4103/ijpvm.IJPVM\\_48\\_19](https://doi.org/10.4103/ijpvm.IJPVM_48_19)
3. Ghosh, B.; Padhy, P.K.; Niyogi, S.; Patra, P.K.; Hecker, M. (2023). A Comparative Study of Heavy Metal Pollution in Ambient Air and the Health Risks Assessment in Industrial, Urban, and Semi-Urban Areas of West Bengal, India: An Evaluation of Carcinogenic, Non-Carcinogenic, and Additional Lifetime Cancer Cases. *Environments.* 10(11):190. Available at: <https://doi.org/10.3390/environments10110190>
4. Bodor, K.; Bodor, Z.; Szép, R. (2021). Spatial Distribution of Trace Elements (As, Cd, Ni, Pb) from PM10 Aerosols and Human Health Impact Assessment in an Eastern European Country, Romania. *Environmental Monitoring and Assessment.* 193(4), 176. Available at: <https://doi.org/10.1007/s10661-021-08931-4>
5. Marques, P.; Piqueras, L.; Sanz, M.J. (2021). An Updated Overview of E-Cigarette Impact on Human Health. *Respir Res.* 22, 151. Available at: <https://doi.org/10.1186/s12931-021-01737-5>
6. Felter, S.P.; Boobis, A.R.; Botham, P.A.; Brousse, A.; Greim, H.; Hollnagel, H.M.; Sauer, U.G. (2020) Hazard Identification, Classification, and Risk Assessment of Carcinogens: Too Much or Too Little? – Report of an ECETOC Workshop. *Critical Reviews in Toxicology.* 50:1, 72-95. Available at: <https://doi.org/10.1080/10408444.2020.1727843>
7. Nirmalkar, J.; Lee, K.; Ahn, J.; Lee, J.; Song, M. (2023). Comparisons of Spatial and Temporal Variations in PM2.5-Bound Trace Elements in Urban and Rural Areas of South Korea, and Associated Potential Health Risks. *Atmosphere.* 14(4):753. Available at: <https://doi.org/10.3390/atmos14040753>

8. Adamkiewicz, G.; Liddie, J.; Gaffin, J.M. (2020). The Respiratory Risks of Ambient/Outdoor Air Pollution. *Clinics in Chest Medicine*. 41(4), 809–824. Available at: <https://doi.org/10.1016/j.ccm.2020.08.013>
9. Chao, X.; Yi, L.; Lan, L.L.; Wei, H.Y.; Wei, D. (2020). Long-term PM2.5 Exposure Increases the Risk of Non-Small Cell Lung Cancer (NSCLC) Progression by Enhancing Interleukin-17a (IL-17a)-Regulated Proliferation and Metastasis. *Aging*. 12(12), 11579–11602. Available at: <https://doi.org/10.18632/aging.103319>
10. Yuan, Z.; Nag, R.; Cummins, E. (2022). Human Health Concerns Regarding Microplastics in the Aquatic Environment - From Marine to Food Systems. *Science of The Total Environment*. Volume 823, 153730. Available at: <https://doi.org/10.1016/j.scitotenv.2022.153730>
11. Kermani, M.; Jonidi Jafari, A.; Gholami, M.; Arfaeinia, H.; Shahsavani, A.; Fanaei, F. (2021). Characterization, Possible Sources and Health Risk Assessment of PM2.5-bound Heavy Metals in the Most Industrial City of Iran. *Journal of Environmental Health Science & Engineering*. 19(1), 151–163. Available at: <https://doi.org/10.1007/s40201-020-00589-3>
12. Kelly, F.J.; Fussell, J.C. (2020). Toxicity of Airborne Particles-Established Evidence, Knowledge Gaps and Emerging Areas of Importance. *Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences*. 378(2183), 20190322. Available at: <https://doi.org/10.1098/rsta.2019.0322>
13. Humairoh, G.P.; Syafei, A.D.; Santoso, M.; Boedisantoso, R.; Assomadi, A.F.; Hermana, J. (2020). Identification of Trace Element in Ambient Air Case Study: Industrial Estate in Waru, Sidoarjo, East Java. *Aerosol Air Qual. Res.* 20: 1910–1921. Available at: <https://doi.org/10.4209/aaqr.2019.11.0590>
14. Dastizadeh, M.; Kamani, H.; Ashrafi, S.D.; Panahi, A.H.; Mahvi, A.H.; Balarak, D.; Hoseini, M.; Ansari, H.; Bazrafshan, E.; Parsafar, F. (2019). Human Health Risk Assessment of Trace Elements in Drinking Tap Water in Zahedan City, Iran. *Journal of Environmental Health Science & Engineering*. 17(2), 1163–1169. Available at: <https://doi.org/10.1007/s40201-019-00430-6>
15. Hua, C.; Ma, W.; Zheng, F.; Zhang, Y.; Xie, J.; Ma, L.; Song, B.; Yan, C.; Li, H.; Liu, Z.; Liu, Q.; Kulmala, M.; Liu, Y. (2023). Health Risks and Sources of Trace Elements and Black Carbon in PM2.5 from 2019 to 2021 in Beijing. *Journal of Environmental Sciences*. Available at: <https://doi.org/10.1016/j.jes.2023.05.023>
16. Knoell, D.L.; Wyatt, T.A. (2021). The Adverse Impact of Cadmium on Immune Function and Lung Host Defense. *Seminars in Cell & Developmental Biology*. 115, 70–76. Available at: <https://doi.org/10.1016/j.semcdb.2020.10.007>
17. Jaishankar, M.; Tseten, T.; Anbalagan, N.; Mathew, B.B.; Beeregowda, K.N. (2014). Toxicity, Mechanism and Health Effects of Some Heavy Metals. *Interdisciplinary Toxicology*. 7(2), 60–72. Available at: <https://doi.org/10.2478/intox-2014-0009>
18. Shin, D.Y.; Lee, S.M.; Jang, Y.; Lee, J.; Lee, C.M.; Cho, E.M.; Seo, Y.R. (2023). Adverse Human Health Effects of Chromium by Exposure Route: A Comprehensive Review Based on Toxicogenomic Approach. *International Journal of Molecular Sciences*. 24(4), 3410. Available at: <https://doi.org/10.3390/ijms24043410>
19. Hessel, E.V.S.; Staal, Y.C.M.; Piersma, A.H.; den Braver-Sewradj, S.P.; Ezendam, J. (2021). Occupational Exposure to Hexavalent Chromium. Part I. Hazard Assessment of Non-cancer Health Effects. *Regulatory Toxicology and Pharmacology*. 126, 105048. Available at: <https://doi.org/10.1016/j.yrtph.2021.105048>
20. Ren, C.; Zhou, Y.; Liu, W. et al. (2021). Paradoxical Effects of Arsenic in the Lungs. *Environ Health Prev Med*. 26, 80. Available at: <https://doi.org/10.1186/s12199-021-00998-2>
21. Hvidtfeldt, U.A.; Severi, G.; Andersen, Z.J.; Atkinson, R.; Bauwelinck, M.; Bellander, T.; et al. (2021). Long-term Low-level Ambient Air Pollution Exposure and Risk of Lung Cancer – A Pooled Analysis of 7 European Cohorts. *Environment International*. 146, 106249. Available at: <https://doi.org/10.1016/j.envint.2020.106249>
22. Muzaffar, S.; Khan, J.; Srivastava, R.; et al. (2023). Mechanistic Understanding of the Toxic Effects of Arsenic and Warfare Arsenicals on Human Health and Environment. *Cell Biol Toxicol*. 39, 85–110. Available at: <https://doi.org/10.1007/s10565-022-09710-8>



23. Hayashi, F.; Kido, T.; Sakamoto, N.; Zaizen, Y.; Ozasa, M.; Yokoyama, M.; Yura, H.; Hara, A.; Ishimoto, H.; Yamaguchi, H.; et al. (2020). Pneumoconiosis with a Sarcoid-Like Reaction Other than Beryllium Exposure: A Case Report and Literature Review. *Medicina*. 56(11), 630. Available at: <https://doi.org/10.3390/medicina56110630>
24. Toyooka, T.; Koda, S. (2021). *Sangyo Eiseigaku Zasshi = Journal of Occupational Health*. 63(2), 31–42. Available at: <https://doi.org/10.1539/sangyoeisei.2020-030-A>
25. Li, T.; Yu, Y.; Sun, Z.; et al. (2022). A Comprehensive Understanding of Ambient Particulate Matter and its Components on the Adverse Health Effects Based from Epidemiological and Laboratory Evidence. *Part Fibre Toxicol*. 19, 67. Available at: <https://doi.org/10.1186/s12989-022-00507-5>
26. Parris, B.A.; O'Farrell, H.E.; Fong, K.M.; Yang, I.A. (2019). Chronic Obstructive Pulmonary Disease (COPD) and Lung Cancer: Common Pathways for Pathogenesis. *Journal of Thoracic Disease*. 11(Suppl 17), S2155–S2172. Available at: <https://doi.org/10.21037/jtd.2019.10.54>
27. Guo, H.; Liu, H.; Wu, H.; Cui, H.; Fang, J.; Zuo, Z.; Deng, J.; Li, Y.; Wang, X.; Zhao, L. (2019). Nickel Carcinogenesis Mechanism: DNA Damage. *International Journal of Molecular Sciences*. 20(19), 4690. Available at: <https://doi.org/10.3390/ijms20194690>
28. Quality Assurance Handbook for Air Pollution Measurement Systems. (2009). Volume IV: Meteorological Measurements Version 2.0
29. USEPA. Air Sampling Procedure. (2023). Method 201A - PM10 and PM2.5 - Constant Sampling Rate Procedure. Available at: <https://www.ecfr.gov/cgi-bin/ECFR>
30. USEPA. Framework for Heavy Metals Risk Assessment. (2020). Method No. EPA120/R/001 – March 2007. Available at: <https://www.epa.gov/risk/framework-metals-risk-assessment>
31. Abbass, K.; Qasim, M.Z.; Song, H.; et al. (2022). A Review of the Global Climate Change Impacts, Adaptation, and Sustainable Mitigation Measures. *Environ Sci Pollut Res*. 29, 42539–42559. Available at: <https://doi.org/10.1007/s11356-022-19718-6>
32. Waheeb, S.; Bilel, Z.; Elbeltagi, A.; Alwetaishi, M.; Wong, Y.J.; Bailek, N.; Alsaggaf, A.; Abd Elrahman, S.; Santos, C.; Majrashi, A. (2023). Enhancing Sustainable Urban Planning through GIS and Multiple-Criteria Decision Analysis: A Case Study of Green Space Infrastructure in Taif Province, Saudi Arabia. *Water*. 15, 3031. Available at: <https://doi.org/10.3390/w15173031>
33. Farahat, A.; Chauhan, A.; Al Otaibi, M.; et al. (2021). Air Quality Over Major Cities of Saudi Arabia During Hajj Periods of 2019 and 2020. *Earth Syst Environ*. 5, 101–114. Available at: <https://doi.org/10.1007/s41748-021-00202-z>
34. Lickiewicz, J.; Piotrowicz, K.; Hughes, P.P.; Makara-Studzńska, M. (2020). Weather and Aggressive Behavior among Patients in Psychiatric Hospitals-An Exploratory Study. *Int J Environ Res Public Health*. 17(23), 9121. Available at: <https://doi.org/10.3390/ijerph17239121>
35. Rahman, A.; Kumar, P.; Dominguez, F. (2022). Increasing Freshwater Supply to Sustainably Address Global Water Security at Scale. *Sci Rep*. 12, 20262. Available at: <https://doi.org/10.1038/s41598-022-24314-2>
36. Li, M.; Huang, X.; Zhu, L.; Li, J.; Song, Y.; Cai, X.; Xie, S. (2011). Analysis of the Transport Pathways and Potential Sources of PM10 in Shanghai Based on Three Methods. *The Science of the Total Environment*. 414, 525-34. Available at: <https://doi.org/10.1016/j.scitotenv.2011.10.054>
37. Ladd, C.; Cheng, W.; Salo, S. (2015). Gap Winds and Their Effects on Regional Oceanography Part II: Kodiak Island, Alaska. *Deep Sea Research Part II: Topical Studies in Oceanography*. 132. Available at: <https://doi.org/10.1016/j.dsr2.2015.08.005>
38. Lai, H.-C.; Dai, Y.-T.; Mkasimongwa, S.W.; Hsiao, M.-C.; Lai, L.-W. (2023). The Impact of Atmospheric Synoptic Weather Condition and Long-Range Transportation of Air Mass on Extreme PM10 Concentration Events. *Atmosphere*. 14, 406. Available at: <https://doi.org/10.3390/atmos14020406>
39. Czernecki, B.; Pórolniczak, M.; Kolendowicz, L.; et al. (2017). Influence of the Atmospheric Conditions on PM10 Concentrations in Poznań, Poland. *J Atmos Chem*. 74, 115–139. Available at: <https://doi.org/10.1007/s10874-016-9345-5>

40. Bodor, Z.; Bodor, K.; Keresztesi, Á.; et al. (2020). Major Air Pollutants Seasonal Variation Analysis and Long-Range Transport of PM<sub>10</sub> in an Urban Environment with Specific Climate Condition in Transylvania (Romania). *Environ Sci Pollut Res.* 27, 38181–38199. Available at: <https://doi.org/10.1007/s11356-020-09838-2>
41. Hodgson, E.C.; Phillips, I.D. (2021). Seasonal Variations in the Synoptic Climatology of Air Pollution in Birmingham, UK. *Theor Appl Climatol.* 146, 1421–1439. Available at: <https://doi.org/10.1007/s00704-021-03779-7>
42. McCabe, M.; Alshalan, M.; Hejazi, M.; Beck, H.; Maestre, F.; Guirado, E.; Peixoto, R.; Duarte, C.; Wada, Y.; Al-Ghamdi, S.G.; Saud, N.; Underwood, M.; Magistretti, P.; Gallouzi, I. (2023). Climate Futures Report: Saudi Arabia in a 3-degrees Warmer World. Available at: <https://doi.org/10.25781/KAUST-8XY63>
43. Almuqati, R.R.; Alamri, A.S.; Almuqati, N.R. (2019). Knowledge, Attitude, and Practices Toward Sun Exposure and Use of Sun Protection Among Non-medical, Female, University Students in Saudi Arabia: A Cross-sectional Study. *Int J Womens Dermatol.* 5(2), 105-109. Available at: <https://doi.org/10.1016/j.ijwd.2018.11.005>
44. Rahim, A.A.; Noor, N.M.; Jafri, M.I.A.; Ul-Saufie, A.Z.; Ramli, N.; Seman, N.A.A.; Kamarudzaman, A.N.; Zainol, M.R.A.; Victor, S.A.; Deak, G. (2023). Variability of PM<sub>10</sub> Level with Gaseous Pollutants and Meteorological Parameters During Episodic Haze Event in Malaysia: Domestic or Solely Transboundary Factor? *Heliyon.* 9(6), e17472. Available at: <https://doi.org/10.1016/j.heliyon.2023.e17472>
45. Bodor, Z.; Bodor, K.; Keresztesi, Á.; Szép, R. (2020). Major Air Pollutants Seasonal Variation Analysis and Long-Range Transport of PM<sub>10</sub> in an Urban Environment with Specific Climate Condition in Transylvania (Romania). *Environ Sci Pollut Res Int.* 27(30), 38181-38199. Available at: <https://doi.org/10.1007/s11356-020-09838-2>
46. Yan, H.; Li, Q.; Feng, K.; et al. (2023). The Characteristics of PM Emissions from Construction Sites During the Earthwork and Foundation Stages: An Empirical Study Evidence. *Environ Sci Pollut Res.* 30, 62716–62732. Available at: <https://doi.org/10.1007/s11356-023-26494-4>
47. Surit, P.; Wongtanasarasin, W.; Boonnag, C.; Wittayachamnankul, B. (2023). Association between Air Quality Index and Effects on Emergency Department Visits for Acute Respiratory and Cardiovascular Diseases. *PLoS One.* 18(11), e0294107. Available at: <https://doi.org/10.1371/journal.pone.0294107>
48. Adly, H.; Saleh, S.; Saati, A.; Fatani, S. (2017). Cancer Risk of Inhalation Exposure to Cd, Cr, As, Be and Ni in Ambient Air. *Journal of Environmental Protection.* 8, 290-300. Available at: <https://doi.org/10.4236/jep.2017.83022>
49. Abatemi-Usman, S.; Akindele, O.; Ayanlade, A.; et al. (2023). Trace Elements Concentrations in Soil Contaminate Corn in the Vicinity of a Cement-Manufacturing Plant: Potential Health Implications. *J Expo Sci Environ Epidemiol.* 33, 813–823. Available at: <https://doi.org/10.1038/s41370-023-00548-8>
50. Aldekheel, M.; Farahani, V.J.; Sioutas, C. (2023). Assessing Lifetime Cancer Risk Associated with Population Exposure to PM-Bound PAHs and Carcinogenic Metals in Three Mid-Latitude Metropolitan Cities. *Toxics.* 11(8), 697. Available at: <https://doi.org/10.3390/toxics11080697>
51. Rybak, J.; Wróbel, M.; Białowicz, J.S.; Rogula-Kozłowska, W. (2020). Selected Metals in Urban Road Dust: Upper and Lower Silesia Case Study. *Atmosphere.* 11, 290. Available at: <https://doi.org/10.3390/atmos11030290>
52. Al, S.; Baljoon, M.J.; Zubairi, N.A.; Dhafar, K.O.; Gazzaz, Z.J.; Deiab, B.A.; Hothali, F.A. (2015). Pattern of Patients and Diseases During Mass Transit: The Day of Arafat Experience. *Pak J Med Sci.* 31(5), 1099-103. Available at: <https://doi.org/10.12669/pjms.315.8017>
53. Ahn, K.; Chu, Z.; Lee, D. (2021). Effects of Renewable Energy Use in the Energy Mix on Social Welfare. *Energy Econ.* 96, 105174. Available at: <https://doi.org/10.1016/j.eneco.2021.105174>



## Assessing the heatwaves trend in Makkah Province 1983 - 2016 using high-resolution (CHIRTS-daily) data

Eman Albalawi\*, Hadeel Wasili & Rawan AlSharif

Department of Geography, Umm Al-Qura University, Makkah, Saudi Arabia.

\*Corresponding author: E-mail (ekbalawi@uqu.edu.sa)

## تقييم اتجاه الموجات الحارة في منطقة مكة المكرمة 1983-2016م باستخدام بيانات عالية الدقة لـ (CHIRTS-daily)

إيمان خالد البلوي\*، هديل الواصلي، روان الشريف

قسم الجغرافيا، جامعة أم القرى

### الملخص

في هذا الوقت الذي يتسم بتغير المناخ وارتفاع درجات الحرارة العالمية، يمكن أن تؤثر موجات الحر الشديدة بشدة على صحة الإنسان. تعتبر مكة المكرمة في المملكة العربية السعودية مدينة مقدسة مهمة للمسلمين، حيث يؤدي ملايين المسلمين من جميع أنحاء العالم مناسك الحج أو العمرة سنويًا. من الأولويات القصوى لرؤية المملكة العربية السعودية 2030 زيادة عدد الحجاج وإثراء الرحلات الروحية للحجاج. ويجب تحديد التدابير اللازمة للتخفيف من موجات الحر والتركيز على توفير استراتيجيات الكفاءة لراحة الحجاج وسلامتهم. تهدف هذه الدراسة إلى استكشاف موجات الحر في مكة المكرمة من عام 1983 إلى عام 2016 باستخدام بيانات تقديرات الحرارة الشديدة العالمية السنوية عالية الدقة (GEHE) المتاحة عالية الدقة لزيادة المعرفة والوعي بالمناخ المحلي وكمقدمة لنمذجة موجات الحر الشديدة المستقبلية. تم استخدام بيانات تقديرات الحرارة القصوى العالمية السنوية عالية الدقة (GEHE) مع عتبة WBGTmax البالغة 32 درجة مئوية وفقًا لمعايير ISO للمخاطر المهنية المرتبطة بالحرارة لاستكشاف موجات الحر في مكة المكرمة. قدمت بيانات GEHE للفترة 1983-2016 عدد الأيام التي تجاوزت عتبة 32 درجة مئوية لسنة معينة والمعدل السنوي للزيادة في الأيام في السنة (بيانات الاتجاه). كان المعدل السنوي للزيادة في عدد الأيام سنويًا من عام 1983 إلى عام 2016 والذي تجاوز عتبة 32 درجة مئوية هو 2.30 يومًا مع زيادة أيام التعرض لموجات الحر لنفس الفترة بمقدار 49 يومًا (106 إلى 155 يومًا). على الرغم من أن مجموعة البيانات ليست حديثة، فقد أظهرت النتائج الأولية أن مكة المكرمة لديها حاجة ملحة لمواصلة اعتماد التخفيف المستهدف لموجات الحر وإضافة أنظمة الإنذار المبكر للحد من الضرر المحتمل لموجات الحر الشديدة. ويمكن استخدام النتائج لإبلاغ صناع القرار في وزارة الحج والعمرة لرؤية 2030 التي تهدف إلى زيادة عدد الحجاج وإثراء الرحلات الروحية للحجاج. وتتمثل الخطوات التالية في دراسة المزيد من البيانات المناخية الحالية لمكة المكرمة لمواصلة تقييم موجات الحر ونمذجة الاتجاهات المستقبلية باستخدام التقنيات الجغرافية المكانية.

الكلمات الدالة: موجة الحر الشديدة؛ تغير المناخ؛ مكة؛ المملكة العربية السعودية.

### Abstract:

In this time of climate change and increasing global temperatures, extreme heatwave events can severely impact human health. Makkah in Saudi Arabia is an important holy city for Muslims, with millions of Muslims from around the world performing Hajj or Umrah annually. A top priority for the Saudi Arabia 2030 vision is increasing the number of Hajj

pilgrims and enriching pilgrims' spiritual journeys. Measures to mitigate heat waves and focus on providing efficiency strategies for pilgrims' comfort and safety need to be determined. This study aims to explore heatwaves in Makkah from 1983 to 2016 using available high-resolution Annual Global High-Resolution Extreme Heat Estimates (GEHE) data to increase knowledge and awareness of the local climate and as a precursor to future extreme heat wave modeling. The Annual Global High-Resolution Extreme Heat Estimates (GEHE) data with the WBGTmax threshold of 32°C ISO criterion for occupational heat-related risk were used to explore heatwaves in Makkah. GEHE data for 1983–2016 provided the number of days that exceeded the 32°C threshold for a given year and the annual rate of increase in days per year (trend data). The annual rate of increase in days per year from 1983 to 2016 exceeding the 32°C threshold was 2.30 days with heatwave exposure days for the same period increasing by 49 days (106 to 155 days). The results show the highest number of heatwave days with temperature increases occurred in 2016, relative to the remaining years analyzed, over Makkah. Despite the dataset not being current, preliminary results showed that Makkah has an urgent need to continue to adopt targeted heatwave mitigation and add early warning systems to reduce the potential harm of extreme heatwaves. The findings can be used to inform decision-makers at the Ministry of Hajj and Umra about the 2030 vision, which aims to increase the number of Hajj pilgrims and enrich pilgrims' spiritual journeys. The next steps are to investigate more current climate data for Makkah to further assess heatwaves and model future trends using geospatial techniques.

**Keywords:** Extreme heatwave; temperature; climate change; Makkah; Saudi Arabia.

## 1. Introduction

Temperature is one of the most important elements for climate forecasting. Assessing and exploring temperature behaviour is, therefore, important to understand spatial and temporal climate variability at different local, regional, and global scales. Climate change disrupts numerous aspects of terrestrial natural systems, such as increasing global temperature. Extreme heatwave events because of global warming can severely impact human health and have the potential to change the ecology of disease vectors (Neira et al., 2023).

Makkah in Saudi Arabia is an important holy city for Muslims, with millions of Muslims from around the world performing Hajj or Umrah annually. The five-day Islamic Hajj pilgrimage takes place in the 12th month (Dhul-Hijjah) of the Islamic calendar of which 20 to 30 hours involve being outside in the open air. Visitors usually arrive one or two weeks before the Hajj begins and remain for a week after. Pilgrims are particularly at risk from increases in extreme heat. The physiological impacts of extreme heat waves such as sunstroke and heat exhaustion are the main challenges for pilgrims. Elderly pilgrims, those unaccustomed to high-heat environments, and people with chronic illnesses are more vulnerable to high-risk extreme heat waves. When the Hajj falls during periods of high temperature participants will be exposed to extreme heat effects outdoors. Measures to limit health problems during the Hajj have been undertaken. For example, participants are educated to stay in shelters for protection, use sunblock, and intake adequate water (Galal & Salem, 2003; Al-Masud et al., 2016) and if possible, encouraged to be flexible with time and perform rites during the night (Al-Masud et al., 2016). The government of Saudi Arabia through the Ministry of Hajj has also been taking measures such as installing nozzles that provide a mist of water in some of the outdoor locations as evaporative cooling for pilgrims and widening some areas to reduce overcrowding (Shafi et al., 2016).

Saudi Arabia is situated in a desert climate zone symbolized by high temperatures, and low and irregular rainfall (Kottek et al., 2006). Based on the projection of a global temperature rise by 1.5°C (2.7°F) (Masson, 2018), most of the population

in Saudi Arabia will be exposed to increased extreme heat effects. An increase in temperature of 0.65°C per decade has already been reported by Almazroui et al. (2014), while extreme temperature events are becoming more frequent (Athar, 2014). A top priority for the Saudi Arabia 2030 vision is increasing the number of Hajj pilgrims and enriching pilgrims' spiritual journeys. Measures to mitigate heat waves and focus on providing efficiency strategies for pilgrims' comfort and safety need to be determined.

Past heatwaves have gone unreported across arid Saudi Arabia with the extent and trend of heat-related impacts remaining unknown. Heatwaves are generally not documented or properly understood as a risk across the country. With Makkah highly vulnerable to increased extreme heat due to climate change (Saeed et al., 2021), future climate change will likely increase the frequency and intensity of heatwaves during the Hajj period at Makkah holy sites. This study aims to explore heatwaves in Makkah from 1983 to 2016 using available high-resolution Annual Global High-Resolution Extreme Heat Estimates (GEHE) data to increase knowledge and awareness of the local climate and as a precursor to future extreme heatwave modeling.

## 2. Methodology:

### Study area

Makkah is in Western Saudi Arabia located between 21° 25' 21.0360' N and 39° 49' 34.2048' E (Fig. 1). Makkah covers an administrative area of 141,216 km<sup>2</sup> with a population of around 2 million within the city, with 26% of the population of Saudi Arabia concentrated in the Makkah region (GASTAT, 2022). The climate of Makkah is characterized by arid-desert-hot (BWh) according to Köppen-Geiger's climate classification (Kottek et al., 2006).

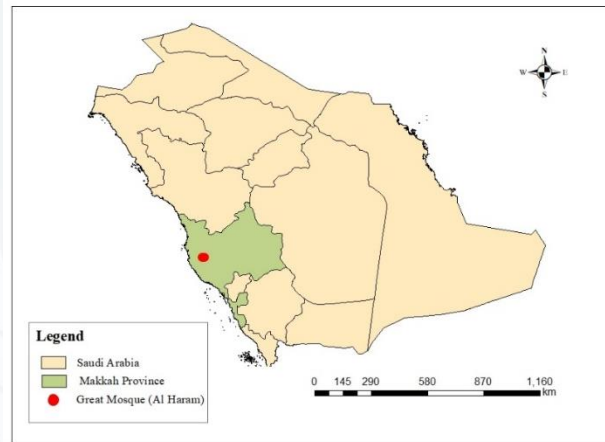


Figure 1. Location of the study area Makkah Province.

### Data:

The Annual Global High-Resolution Extreme Heat Estimates (GEHE) data (Tuholske et al., 2023) were used to explore heat waves in Makkah. GEHE data provides global 0.05 degrees (~5 km) gridded annual counts of the number of days where the maximum Wet Bulb Globe Temperature (WBGT<sub>max</sub>) exceeded dangerous hot-humid heat thresholds for the period 1983 to 2016. This dataset is openly available through: <https://sedac.ciesin.columbia.edu/>. The WBGT<sub>max</sub> threshold of 32°C based on an International Standards Organization (ISO) criterion for occupational heat-related risk was selected as the most appropriate temperature standard for Makkah for this study. Daily climate data (T2M\_MAX and T2M\_MIN) for the period 1983 to 2016 were also used. Data were obtained from the National Aeronautics and Space

Administration (NASA) Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (POWER) Project funded through the NASA Earth Science/Applied Science Program.

**Analyses:**

Annual GEHE data for 1983 – 2016 provided the number of days that exceeded the 32°C threshold for a given year and the annual rate of increase in days per year (trend data). Global data were available in GeoTIFF format (unprojected using the EPSG:4326 (WGS84) Geographic Coordinate System) and clipped to fit the area of interest in ArcGIS Software (ArcMap 10).

Extreme heat maps were generated for the years 1983, 1993, 2003, 2013, and 2016 in ArcMap. Daily and average monthly climate data (T2M\_MAX and T2M\_MIN) for the period 1983 to 2016 were also explored. For Long-Term Trends analysis, ordinary least-squares linear regression models were used. Trends were estimated as the slope of a linear trend model using data from 1983 to 2016. For computing seasonal values climatological seasons for Makkah are used, i.e. December to February for winter, March to May for spring, June to August for summer, and September to November for autumn.

**3. Results & discussion:**

The annual count of daily extreme heat across Makkah using the WBGTmax 32°C threshold showed the greatest number of heatwave days occurred in 2016 (155) covering most of the urban areas of Makkah (Fig 2). The average number of heatwave days increased by 49 days, from 106 days in 1983 to 155 days in 2016 (Fig 2), while 1993 had the lowest number of days above the threshold of 32°C (90 days) over the period. The annual (trend) rate of increase of 2.30 days per year exceeding WBGTmax of 32°C from 1983 to 2016 in Makkah was statistically significant at  $p < 0.05$ . The daily maximum temperatures in the study area between 1983 and 2016 ranged between 47.82°C and 17.19°C with a standard deviation of 5.55°C, with daily minimum temperatures ranging between 31.56°C and 6.98°C with a standard deviation of 4.88°C during 1983 – 2016 (Table 1).

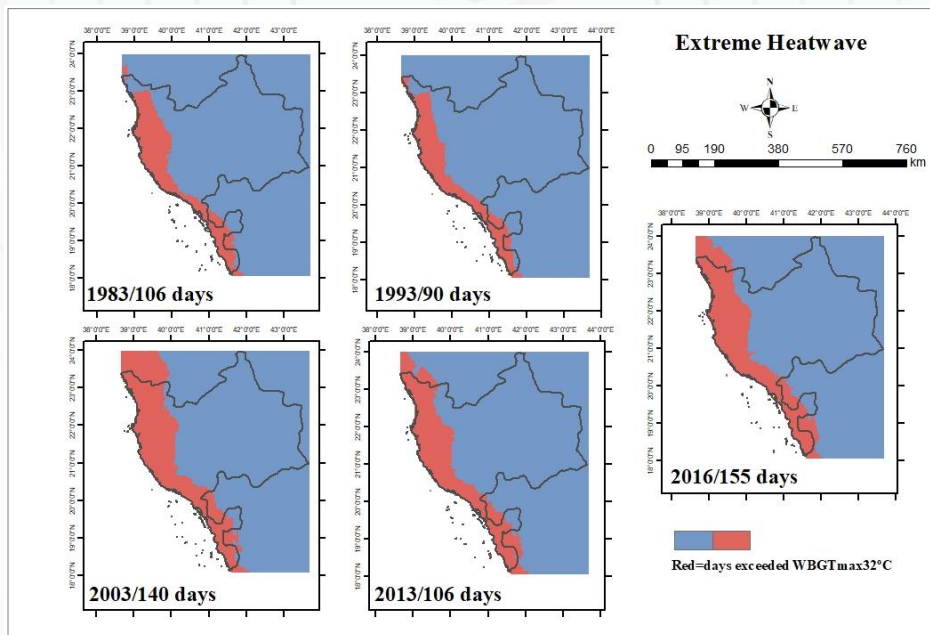


Figure 2. Annual heatwave days in the study area using WBGTmax 32°C.

Table 1. Daily temperature data summary for Makkah during 1983 – 2016

	Max (°C)	Min (°C)	Mean (°C)	Std. dev. (°C)
T2M_MAX	47.82	17.19	36.58	5.55
T2M_MIN	31.56	6.98	22.65	4.88

The general trend of daily maximum and minimum temperatures in the studied area, where the linear regression equations show a slope value (T2M\_MAX  $y = 0.0016x$  and T2M\_MIN  $y = 0.0018x$ ). Indicating the rate of change to be  $0.0016^{\circ}\text{C}/33$  years from 1983 to 2016 which is lower than the global warming rate estimated at  $0.08^{\circ}\text{C}$  for the last decade (NOAA, 2021). Monthly mean temperatures show temperature increases on an annual scale resulting from a pronounced May (spring) to July (summer) warming (Table 2). Results indicate that September was the warmest period for Hajj with a mean temperature of  $42^{\circ}\text{C}$  in 1983 and 2016, with September reaching similar mean temperature values to those experienced in the summer months (Table 2).

Most mean temperatures in Makkah exceeded  $35^{\circ}\text{C}$  from May to October (spring, summer, and autumn) (Table 2), which is above  $32^{\circ}\text{C}$  considered the upper limit globally at which sustained physical activity is possible (Buzan et al., 2015; Coffel et al., 2017; Saeed et al., 2021).

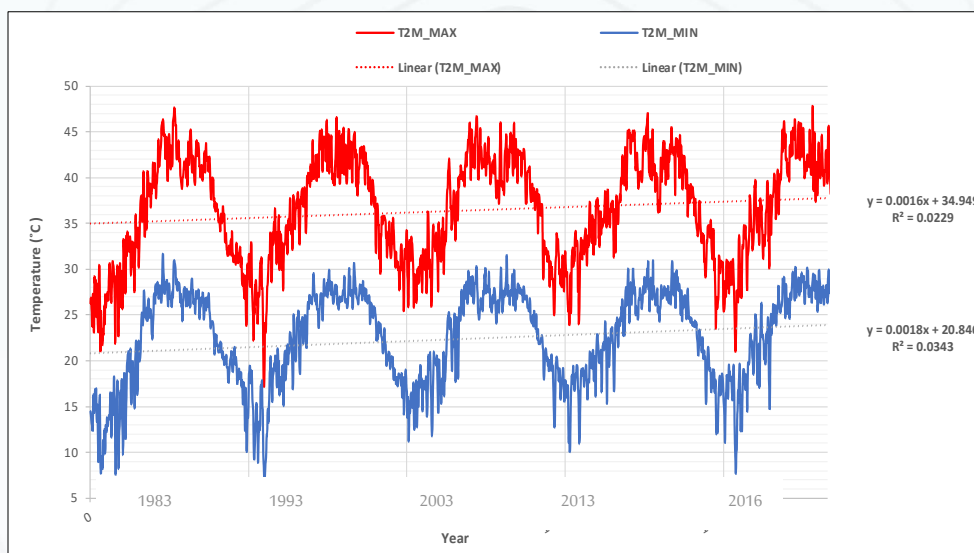


Figure 3. Daily maximum and minimum temperatures during the period (1983 – 2016)

Table 2. Monthly mean, maximum, and minimum temperatures for Makkah for years 1983, 1993, 2003, 2013, and 2016

Year \ Month	1983	1993	2003	2013	2016
	mean (max, min) °C	mean (max, min) °C	mean (max, min) °C	mean (max, min) °C	mean (max, min) °C
January	26 (30, 8)	28 (33, 9)	30 (34, 11)	29 (34, 10)	28 (31, 8)
February	28 (31, 8)	28 (35, 7)	30 (36, 12)	33 (37, 11)	32 (38, 12)
March	29 (34, 8)	33 (37, 15)	32 (36, 14)	35 (38, 16)	35 (40, 17)
April	33 (38, 15)	36 (38, 17)	38 (42, 18)	36 (39, 15)	36 (40, 15)
May	38 (42, 22)	39 (44, 21)	42 (46, 24)	41 (45, 21)	41 (46, 25)
June	43 (46, 26)	43 (46, 24)	43 (47, 25)	42 (45, 24)	44 (46, 27)
July	43 (48, 26)	42 (46, 26)	41 (44, 24)	42 (47, 25)	42 (48, 26)
August	41 (45, 24)	42 (45, 26)	42 (46, 25)	41 (44, 24)	42 (46, 25)

September	42 (44, 25)	41 (45, 26)	42 (46, 25)	43 (46, 24)	42 (47, 25)
October	38 (42, 21)	37 (41, 22)	38 (41, 22)	38 (42, 22)	38 (41, 22)
November	33 (37, 18)	34 (36, 18)	33 (38, 18)	34 (37, 15)	34 (37, 18)
December	30 (33, 10)	31 (34, 14)	30 (34, 13)	30 (35, 12)	31 (34, 16)

Yellow indicates temperatures measured for the Hajj period.

Seasonal temperature differences results (Fig 4) showed that an increase in temperature was positively correlated with seasonal differences for spring between 1983 and 2016 ( $R^2=0.89$ ), which is consistent with observations of a global temperature increase in spring as noted for several global studies (Altın et al., 2012; Ghasemi, 2015). Spring showing the strongest seasonal trend (Fig 4) reflects the high summer-like September T2M\_MAX values and mean temperature (Table 2) of June, July, and August temperature values. The 2016 Hajj heatwave caused significant heatstroke (29%), heat exhaustion (67.75%), and mortality (6.3%) as reported by Abdelmoety et al. (2018).

The negative correlation of the autumn temperature trend showed a cooling trend with statistically significant results ( $R^2 = 0.83$ ) (Fig 4), similar to those found in global surface temperature change (Hansen et al., 2010). There was little change in the temperature trends for both winter and summer seasons from 1983 to 2016 (Fig 4).

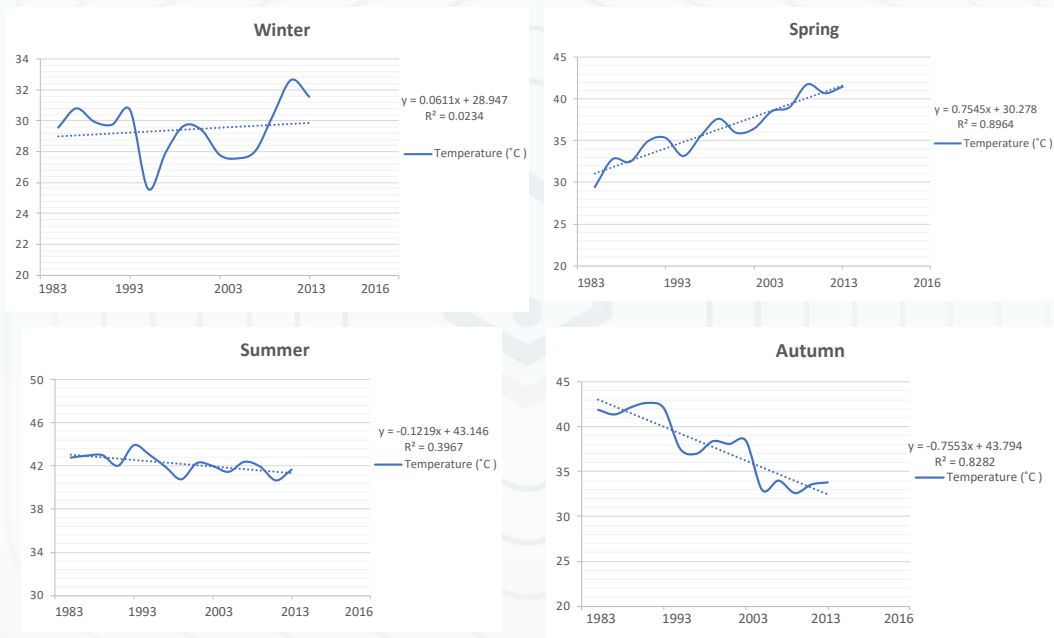


Figure 4. The trend of seasonal temperatures from 1983 to 2016

#### 4. Conclusion:

This study is one of the first to explore heatwaves and trends on a high-resolution (~5 km) scale across Makkah, using the remotely sensed annual GEHE temperature dataset for the period of 1983–2016. The risks to which Hajj participants are exposed to heat may be truly serious in the coming years when the Hajj season coincides with the hottest months. Measures used to mitigate heatwave-related health problems have limitations for those undertaking pilgrimage and Umrah during heatwaves that go beyond the safe global threshold for sustained physical activity, with heatwaves being indicated in this study to be increasing. An increase in the consecutive occurrence of heatwave days and increased temperature expected within the coming decades may increase the incidence of heat-related disorders and deaths. The



excessive number of days that reflect dangerous heatwave conditions shows the urgent need for increased measures to ensure a safe pilgrimage in current and future climate conditions.

If the ambitions of the Sustainable Development Goals are to be met, additional urban heat mitigation must be prioritized. Collaboration between ministries in the fields of climate, health, and the environment should therefore be developed to study the consequences of climate change on pilgrims' health and the population of Makkah. Makkah has an urgent need to continue to adopt targeted heatwave mitigation and add early warning systems to reduce the potential harm of extreme heatwaves. The findings can be used to inform decision-makers of the Ministry of Hajj and Umrah for the 2030 vision which aims to increase the number of Hajj pilgrims and enrich pilgrims' spiritual journeys.

The next steps are to investigate a larger climate data set with more current climate data for Makkah to assess heatwaves and model future trends further using geospatial techniques. This information and future climate studies could support the need to improve mitigation and preventive extreme heat measures and form part of a heat health warning system that could be used to activate public health actions.

#### References:

- Abdelmoety, D. A., El-Bakri, N. K., Almowalld, W. O., Turkistani, Z. A., Bugis, B. H., Baseif, E. A., & Abu-Shaheen, A. (2018). Characteristics of heat illness during Hajj: a cross-sectional study. *BioMed research international*, 2018.
- Al-Masud, S. M. R., Bakar, A. A., & Yussof, S. (2016). Determining the types of diseases and emergency issues in Pilgrims during Hajj: A literature review. *Stat Inf*, 5(7).
- Almazroui, M., Islam, M. N., Dambul, R., & Jones, P. D. (2014). Trends of temperature extremes in Saudi Arabia. *International Journal of Climatology*, 34(3), 808-826.
- Altın TB, Barak B, Altın BN. (2012). Change in precipitation and temperature amounts over three decades in central Anatolia, Turkey. *Atmospheric and Climate Sciences* 2: 107–125.
- Athar, H. (2014). Trends in observed extreme climate indices in Saudi Arabia during 1979–2008. *International Journal of Climatology*, 34(5), 1561-1574.
- Buzan, J. R., Oleson, K., & Huber, M. (2015). Implementation and comparison of a suite of heat stress metrics within the Community Land Model version 4.5. *Geoscientific Model Development*, 8(2), 151-170.
- Coffel, E. D., Horton, R. M., & De Sherbinin, A. (2017). Temperature and humidity-based projections of a rapid rise in global heat stress exposure during the 21st century. *Environmental Research Letters*, 13(1), 014001.
- Funk, C., Peterson, P., Peterson, S., Shukla, S., Davenport, F., Michaelsen, J., & Mata, N. (2019). A high-resolution 1983–2016 T max climate data record based on infrared temperatures and stations by the Climate Hazard Center. *Journal of Climate*, 32(17), 5639-5658.
- Gabal, M. S., & Salem, K. A. (2003). Pattern of heat stroke and heat exhaustion among pilgrims over 20 years (1982-2001). *The Egyptian Journal of Community Medicine*, 21(3).
- Ghasemi, A. R. (2015). Changes and trends in maximum, minimum and mean temperature series in Iran. *Atmospheric Science Letters*, 16(3), 366-372.
- Hansen, J., Ruedy, R., Sato, M., & Lo, K. (2010). Global surface temperature change. *Reviews of Geophysics*, 48(4).
- Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the Köppen-Geiger climate classification updated.
- Masson-Delmotte, V. (2018). Global warming of 1.5° c: An IPCC Special Report on impacts of global warming of 1.5° c above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. (No Title).

- Neira, M., Erguler, K., Ahmady-Birgani, H., Al-Hmoud, N. D., Fears, R., Gogos, C., & Christophides, G. (2023). Climate change and human health in the Eastern Mediterranean and Middle East: Literature review, research priorities and policy suggestions. *Environmental research*, 216, 114537.
- Pal, J. S., & Eltahir, E. A. (2016). Future temperature in southwest Asia projected to exceed a threshold for human adaptability. *Nature Climate Change*, 6(2), 197-200.
- Parsons, D., Stern, D., Ndanguza, D., & Sylla, M. B. (2022). Evaluation of satellite-based air temperature estimates at eight diverse sites in Africa. *Climate*, 10(7), 98.
- Saeed, F., Schleussner, C. F., & Almazroui, M. (2021). From Paris to Makkah: heat stress risks for Muslim pilgrims at 1.5° C and 2° C. *Environmental Research Letters*, 16(2), 024037.
- Salimi, M., & Al-Ghamdi, S. G. (2020). Climate change impacts on critical urban infrastructure and urban resiliency strategies for the Middle East. *Sustainable Cities and Society*, 54, 101948.
- Shafi, S., Dar, O., Khan, M., Khan, M., Azhar, E. I., McCloskey, B., . & Petersen, E. (2016). The annual Hajj pilgrimage—minimizing the risk of ill health in pilgrims from Europe and opportunity for driving the best prevention and health promotion guidelines. *International journal of infectious diseases*, 47, 79-82.
- Tuholske, C., Caylor, K., Funk, C., Verdin, A., Sweeney, S., Grace, K., .& Evans, T. (2021). Global urban population exposure to extreme heat. *Proceedings of the National Academy of Sciences*, 118(41), e2024792118.
- Tuholske, C., P. Peterson, C. Funk, and K. Caylor. 2023. Annual Global High-Resolution Extreme Heat Estimates (GEHE), 1983-2016. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). <https://doi.org/10.7927/hff0-k565>. Accessed 24 October 2023.
- Verdin, A., Funk, C., Peterson, P., Landsfeld, M., Tuholske, C., & Grace, K. (2020). Development and validation of the CHIRTS-daily quasi-global high-resolution daily temperature data set. *Scientific Data*, 7(1), 303.



## A Narrative Review on the Risk Factors Associated with Falls among Pilgrims during the Hajj and Umrah Seasons in Saudi Arabia

Abdulaziz Awali

Department of Medical Rehabilitation Sciences, Faculty of Applied Medical Sciences, Umm Al-Qura University

\*Corresponding author: E-mail (amawali@uqu.edu.sa)

### استعراض تفصيلي لعوامل الخطر المرتبطة بالسقوط بين الحجاج خلال مواسم الحج والعمرة في المملكة العربية السعودية

عبدالعزیز عوالي

قسم علوم التأهيل الطبي، كلية العلوم الطبية التطبيقية

#### الملخص

مناسك الحج والعمرة في المملكة العربية السعودية تعتبر من الشعائر الدينية الهامة التي تجذب ملايين المسلمين من جميع أنحاء العالم سنويًا. ويمكن أن تزيد البيئة الفريدة والتدفقات العالية للحشود من خطر السقوط، خاصة بين كبار السن والأشخاص الذين يعانون من حالات صحية موجودة مسبقًا. يعد فهم عوامل الخطر المرتبطة بالسقوط في هذا السياق أمرًا بالغ الأهمية لضمان سلامة الحجاج وسير الشعائر الدينية بسلاسة. يهدف هذا الاستعراض التفصيلي إلى توضيح العوامل المختلفة التي قد تسهم في خطر سقوط الحشود المتدفقة خلال أداء المناسك الدينية. تمت مراجعة دقيقة للأبحاث والبيانات السابقة، بما في ذلك الدراسات الرصدية والاستبيانات وسجلات الحالات الطبية، لتحقيق فهم شامل لعوامل خطر السقوط في هذه البيئة الفريدة. تم تحديد عدة عوامل رئيسية تشمل العمر والجنس والحالات الطبية الموجودة مسبقًا واللياقة البدنية والتحديات البيئية مثل الأزدحام والأسطح غير المستوية والإضاءة غير الكافية. بالإضافة إلى ذلك، ظهرت عوامل نفسية مثل الخوف من السقوط وتاريخ السقوط السابق كمؤشرات هامة. تبرز هذه النتائج ضرورة وجود تدخلات مستهدفة تشمل فحوصات صحية قبل الحج وحملات توعية وتعديلات بيئية ودعم طبي معزز في الموقع. يتم اقتراح تشجيع الدعم المجتمعي ودمج حلول تكنولوجية لزيادة سلامة الحجاج بشكل أكبر. يوفر هذا الاستعراض أساسًا قويًا لتطوير السياسات والتدخلات المبنيّة على الأدلة بهدف تقليل خطر السقوط، مما يسهم في تحقيق تجربة حج وعمرة أكثر أمانًا وروحانية لجميع الحاضرين.

#### Abstract

The annual Hajj and Umrah pilgrimages in Saudi Arabia represent significant religious observances, attracting millions of devout individuals worldwide. These pilgrimages' distinctive and densely populated environment notably heightens the risk of falls, especially among the elderly and those with pre-existing health conditions. Understanding the risk factors associated with falls in this setting is crucial to safeguarding the well-being of pilgrims, ensuring the smooth conduct of these religious practices, and upholding their sacred essence. This narrative review aims to investigate the factors contributing to the risk of falls among pilgrims during these religious events. A thorough synthesis of the available literature, encompassing observational studies, surveys, and medical records, was undertaken to comprehensively understand the fall risk factors in this unique environment. Key identified factors included age, gender, pre-existing

medical conditions, physical fitness, and environmental challenges such as crowd congestion, uneven surfaces, and inadequate lighting. Moreover, psychological determinants like fear of falling and a history of previous falls emerged as significant factors. The findings underscore the necessity for targeted interventions, including pre-pilgrimage health screenings, educational initiatives, environmental modifications, and augmented on-site medical support. Promoting community vigilance and integrating technological solutions are proposed to enhance the safety of pilgrims further. This review provides a robust basis for developing evidence-based policies and interventions aimed at minimizing fall risks, thereby fostering a safer and more spiritually enriching pilgrimage experience for all attendees.

## 1. Introduction

Annually, millions of Muslims participate in the Hajj and Umrah pilgrimages in Mecca, Saudi Arabia. These mass gatherings, while spiritually enriching, present various public health challenges, most notably the risk of falls among pilgrims (Alshehri et al., 2021; Khan et al., 2018; Razavi et al., 2011). Falling is the major contributor to death and disability in people above the age of 65 (Hausdorff et al., 2001; Tinetti, 2003). For example, in the United States, 2.8 million individuals were admitted to hospitals due to injuries related to falling in 2014 (Bergen et al., 2016). In the context of Hajj and Umrah, many patients are admitted to hospitals with fractures and other types of traumas due to falling annually (Al-Harthi & Al-Harbi, 2001; Al-Hayani et al., 2023; Alshehri et al., 2021; Khan et al., 2018; Razavi et al., 2011). Thus, understanding the factors that increase the risk of falling may result in decreasing the incidence of falls, which may result in a lower incidence of hospitalization.

The risk of falling is influenced by a complex interaction between intrinsic and extrinsic factors, necessitating a comprehensive approach to understanding and addressing it. Intrinsic factors are those inherent to the individuals. They include physiological aspects like age-related decline in balance and muscle strength, health conditions such as arthritis or cardiovascular diseases, and psychological states including depression and cognitive impairments (Linattiniemi et al., 2009; Moreland et al., 2004; Sanders et al., 2012; Sartini et al., 2010; Tinetti, 2003; Wright et al., 2011). Many pilgrims have pre-existing medical conditions that increase their risk of falling (Gaddoury & Armenian, 2023). These factors play a significant role in determining an individual's vulnerability to falls, especially in the physically demanding context of the Hajj and Umrah.

Extrinsic factors, on the other hand, pertain to the environmental and situational aspects of the pilgrimage. The Hajj and Umrah are characterized by dense crowds, long walking distances, and often harsh climatic conditions. For instance, some pilgrims walk between 5 – 12 km between holy places in hot weather (Owaidah et al., 2023). Given that a great deal of pilgrims with pre-existing medical conditions (Memish et al., 2019), these environmental challenges, combined with the rigorous activities involved in the pilgrimage, can significantly increase the risk of falls, particularly for those already vulnerable due to intrinsic factors.

The aim for this review is to provide a comprehensive overview of the risk factors associated with falls among pilgrims during the Hajj and Umrah seasons in Saudi Arabia. This review will in help in offering a foundation for future research and policy development in this vital area of public health resulting in enhancement of the safety and well-being of the pilgrims.

## 2. Methodology

This literature review was conducted to evaluate the existing literature on intrinsic and extrinsic risk factors contributing to falls among pilgrims during the Hajj and Umrah seasons. First, a comprehensive search was conducted across several

electronic databases, including PubMed, Scopus, Web of Science, and Embase. The search was tailored to include a combination of keywords and MeSH terms relevant to the topic. Terms used in the search included "Hajj," "Umrah," "pilgrimage," "fall risks," "intrinsic factors," "extrinsic factors," "elderly," "balance," and "crowd-related accidents." The search was restricted to articles published in English from January 2000 to November 2023 to ensure the relevance and timeliness of the information. The inclusion criteria specified that articles should focus on fall risks related to the elderly or individuals with medical conditions, including papers in the context of mass gatherings such as the Hajj and Umrah. Both quantitative and qualitative studies were considered, including observational studies, clinical trials, case-control studies, cohort studies, surveys, and systematic reviews. Exclusion criteria included articles that were not peer-reviewed, conference abstracts, and editorials.

Titles and abstracts were screened to identify studies that met the inclusion criteria. Full texts of potentially relevant articles were then retrieved and assessed for eligibility. Key findings from the included studies were extracted. Due to the heterogeneous nature of the studies, a meta-analysis was not feasible. Instead, a narrative synthesis approach was employed to integrate findings and explore patterns across studies.

### 3. Results and Discussion

There were only few studies reporting about falls during Hajj or Umrah. However, the factors that are known to increase the risks of falling were explored among literature related to Hajj and Umrah in order to identify whether these intrinsic or extrinsic factors are present in a significant way among pilgrims. The studies that investigated fall directly in the context of Hajj and Umrah are presented in Table 1.

#### 3.1 Intrinsic Risk Factors

##### 3.1.1 Demographic-related Risks

There are a number of demographic factors that have been shown to associate with an increase risk of falling. Age is a primary intrinsic factor influencing fall risk. As individuals age, they often experience a natural decline in physical abilities. This includes a decrease in balance, coordination, and muscle strength, making older adults more prone to falls (Rubenstein, 2006). Considering the physically demanding nature of the Hajj and Umrah, which require extensive walking and navigation through crowded spaces, the age-related decline in physical function becomes particularly relevant. Gazubara et al., 2017 found that in population above the age of 65 years old that falling occurred more frequently during walking and around 50% of fallers experienced injuries (Gazubara et al., 2017). Alfelali et al., 2014 reported that some of pilgrims who were admitted to healthcare facilities with foot injuries were elderly with age range reaching up to 85 years (Alfelali et al., 2014). In addition to age, sex has been shown to associate with the risk of falling. For instance, Dunlop et al., 2002 found that women are at significantly greater risk of falling compared to men (Dunlop et al., 2002). Alshehri et al., 2014 reported that falls were common among older adults and in women, with sex difference in falling increases as age increases (Alshehri et al., 2021). Body mass index has been suggested as one of the predictors of fall. Zhao et al., 2022 found that greater body mass index was associated with increased risk of falling in Chinese older adults. This relation between body mass index and falling is not consistent in the literature. Thus, pilgrims who are elderly, women, and overweight need careful attention because they are at greater risk of falling.

##### 3.1.2 Physiological Factors

Physiological factors, notably gait instability and muscle weakness, play a critical role in the risk of falls among pilgrims during the Hajj and Umrah. These factors are particularly pronounced in older adults and individuals with specific

medical conditions, making them a primary focus for preventing falls within this population (Cameron & Nilsagard, 2018). Abnormalities in gait are a significant contributor to falls (Pirker & Katzenschlager, 2017). In the dynamic and often crowded environment of the Hajj and Umrah, a stable gait is crucial for navigating safely through the mass movement of people. Even minor gait abnormalities can significantly disrupt an individual's stability, increasing the risk of tripping or losing balance in an environment where such events can lead to serious injury or stampedes (Shumway-Cook et al., 2007).

The strength of an individual's muscles, especially in the lower extremities, is foundational for maintaining postural balance and providing the necessary reactions to prevent a fall (Granacher et al., 2013). Muscle weakness can lead to an inability to correct posture quickly when balance is lost, which is an essential component of fall prevention (Rodrigues et al., 2022). This weakness may be due to muscular atrophy, which is common in the aging process, or can be a consequence of sedentary lifestyles, nutritional deficiencies, or chronic diseases such as diabetes mellitus (Naruse et al., 2023). Gaddoury et al., 2023 showed that the majority of hospitalized patients during hajj had pre-existing conditions including diabetes, hypertension and other chronic conditions (Gaddoury & Armenian, 2023). Alfelali et al., 2014 reported that walking for long distances during hajj resulted in foot injuries in diabetic pilgrims (Alfelali et al., 2014). In the context of the Hajj and Umrah, where pilgrims may be required to stand for long periods and traverse long distances, the endurance and strength of lower limb muscles are crucial for stability and fall prevention (Moreland et al., 2004).

The human body's coordination heavily relies on the integration of sensory information from the visual, vestibular, and proprioceptive systems (Onofrei & Amaricai, 2022). As individuals age, or when they are afflicted by certain neurological conditions such as Parkinson's disease or peripheral neuropathy, the efficiency and reliability of these sensory systems can deteriorate (Nusbaum, 1999). This can result in an inability to accurately judge distances, perceive obstacles, or detect changes in the walking surface (Vaishya & Vaish, 2020). In addition, the crowded and unpredictable settings of the Hajj and Umrah, with their throngs of people, varying terrains, and the need for constant movement, can be overwhelming even for those with intact sensory systems. Pilgrims with sensory impairments may face even greater challenges, as the environmental demands of these pilgrimages are superimposed on their diminished capacity to process and respond to sensory information. In such dynamic settings, a small misstep can lead to significant consequences, not only for the individual but also for those around them.

### 3.1.3 Health Conditions

A variety of health conditions significantly influence the risk of falls, with each condition contributing in its unique way to the overall vulnerability of an individual. One of those is arthritis, a common condition in older adults, impacts joint function, causing pain and stiffness which can lead to decreased mobility and an increased risk of falling. Lee et al., 2021 found that having arthritis is associated with falls in Korean adults (Lee et al., 2021). Falls are associated with different types of arthritis such as knee osteoarthritis and rheumatoid arthritis (Brenton-Rule et al., 2015; Manlapaz et al., 2019). The Hajj and Umrah require extensive walking and physical activity, which can be particularly challenging for individuals with arthritis. The uneven terrain and crowded conditions can further exacerbate this risk, as quick movements or adjustments are often necessary to navigate through the crowds.

Cognitive impairments, including conditions like dementia and Alzheimer's disease, significantly affect an individual's risk of falling (Montero-Odasso et al., 2012). These conditions can lead to disorientation, impaired judgment, and difficulty in coordinating movements (Tinetti, 2003). In the context of the Hajj and Umrah, where pilgrims must navigate

complex routes and respond to dynamic environmental changes, cognitive impairments can markedly increase the risk of missteps and falls.

Sensory impairments, such as vision or hearing loss, also contribute to fall risk. Visual impairments can affect depth perception and the ability to detect obstacles, while hearing loss can impact spatial awareness and balance (Biju et al., 2022; Dhital et al., 2010). Both are critical in environments with large crowds and variable lighting conditions, as is typical during the Hajj and Umrah.

Neurological disorders such as Parkinson's disease and multiple sclerosis affect the nervous system, leading to issues with balance and muscle control. These disorders can make it challenging to maintain stability, especially in crowded and moving environments like those experienced during the Hajj and Umrah.

Psychological states, such as the fear of falling, can have a substantial impact on fall risk. Fear of falling can lead to a decrease in activity levels, resulting in further physical decline and increased vulnerability to falls (Friedman et al., 2002). Anxiety and other mental health issues can also affect concentration and attention, making navigation through the crowded and unfamiliar environment of the Hajj and Umrah more challenging.

Therefore, screening pilgrims who have at greater risk of falling may help reduce the incidence of falls and maintain their safety and well-being while avoiding the increase in burden in the health care system. The screening could be done on pilgrims before or when they arrive to Saudi Arabia. There are available tools that have been to predict falls in individuals. For example, a systemic review showed that using tools such as Timed Up and Go test and Borg Balance scale together can significantly predict falling in elderly (Park, 2018). Thus, individuals who are at greater risk can receive additional services such as wheelchairs.

### 3.2 Extrinsic Risk Factors

Extrinsic risk factors for falls during the Hajj and Umrah seasons encompass a variety of environmental and situational challenges. These external factors are not specific to the individual but greatly influence the risk of falls within the pilgrimage context. Studies have shown that outdoor falling are more frequent than indoor falling (Kelsey et al., 2012; Li et al., 2006; Li et al., 2014). Li et al., 2006 found that some extrinsic factors may contribute to the increase risk of falling outdoor such as uneven surfaces or the presence of objects that may cause tripping. The study also found that falling outdoor more frequently occurred during walking on the streets or sidewalks (Li et al., 2006). Similarly, Pilgrims face numerous environmental challenges during Hajj and Umrah, which can increase the risk of falls. Razavi et al., 2011 reported that many incidence of falls in Iranian pilgrims were due to falling down from heights, falling down from electrical stairs, or falling on slippery surfaces (Razavi et al., 2011). The terrain of the pilgrimage sites often includes uneven paths, ramps, and steps that can be difficult to navigate, particularly for those with physical impairments. During the Tawaf, the marble flooring, while aesthetically pleasing, can become slippery, especially in the presence of water from the Zamzam sprinklers or after cleaning, increasing the risk of slips and falls. Moreover, the vast expanse of the pilgrimage area can overwhelm pilgrims, leading to fatigue, which compromises balance and coordination. The high temperatures of the Saudi Arabian climate further exacerbate these risks, with heat exposure potentially leading to heat-related illnesses that can impair judgment and physical ability, resulting in an increased risk of falls. In addition, other extrinsic or environmental factors, such as lighting levels, could increase the risk of falling. Some studies suggest that falls are more common in the dark given that older adults may have retinal insensitivity, which results in impaired dark adaptation and greater fall incidence in the dark (McMurdo & Gaskell, 1991).

The sheer volume of pilgrims congregating in a confined space during Hajj and Umrah leads to extreme levels of crowd congestion. Razvie et al., showed many incidence of fracture occurred during Hajj were influenced by overcrowding as a potential mechanism of injury (Razavi et al., 2011). Navigating through such dense crowds can be disorienting and physically demanding, as it requires continuous adjustment and vigilance. The risk of being jostled or bumped increases in such conditions, which can easily lead to falls, particularly for those who are vulnerable due to age or health conditions. Given that environmental factors can increase the risk of falling, it is recommended that the elements that are known to cause falling in Hajj or Umrah should be modified. For example, adding non-slippery surfaces in Haram so that people who are at greater risk of falling can use, or encouraging people who are at risk of falling to be on whailchairs espically in dense areas like during Tawaf. In addition, managing crowds in areas like escalator can also minize the incidce of falls during these religious events.

Table 1: Falls or falls-related injuries that were reported in Hajj

Study	Title of the Study	Finding relevant to Falls or Fall-related Injuries
Al-Hayani et al., 2023	Trauma and Injuries Pattern During Hajj, 1443 (2022): A Cross-Sectional Study	The results showed that the common causes of trauma in Hajj of 2022 were falling and foot twist.
Alshehri et al., 2021	The Prevalence and Factors Associated with Musculoskeletal Pain Among Pilgrims During the Hajj	The results showed high prevalence of falling among women and older pilgrims. The prevalence of falling was around 15%.
Khan et al., 2018	Morbidity and mortality amongst Indian Hajj pilgrims: A 3-year experience of Indian Hajj medical mission in mass-gathering medicine	The results showed that orthopedic injuries such as Colle’s fractures, shoulder dislocation, metatarsal fractures caused by falling or overstepping in mass-gathering were the second most common cause of admission to healthcare facilities during Hajj.
Razavi et al., 2011	Trends in Prevalent Injuries among Iranian Pilgrims in Hajj	The result showed many cases of common injuries among pilgrims including ankle sprains, hand or foot fractures, and tissue contusions. The study also revealed common mechanisms of injuries involving mechanisms like falling down in stairs or escalators or sliding in bathtubs.
Al-Harhi and Al-Harbi, 2001	Accidental injuries during muslim pilgrimage	The results showed that during 12-days period, there has been more one thousands trauma cases including cases of limb fracture that occurred in homes or inside holy places like Haram.

#### 4. Conclusions

The pilgrimage to Hajj and Umrah is a testament to the devotion of millions of Muslims worldwide. Still, it also brings to light significant challenges to the safety and well-being of the pilgrims, especially regarding fall risks. This review has underscored the multifaceted nature of fall risks, emphasizing a spectrum of intrinsic and extrinsic factors that collectively increase the vulnerability of individuals during these religious gatherings. Intrinsic factors, including age-related physiological changes and health conditions such as arthritis and cognitive impairments, as well as muscle weakness and gait instability, have been identified as significant determinants of fall risk. These are exacerbated by the physically demanding requirements of Hajj and Umrah activities. Moreover, extrinsic factors such as the environmental complexity of the pilgrimage sites, crowd congestion, and the extreme temperatures of the Saudi Arabian climate compound these risks, creating an intricate web of challenges to navigate.

The findings from this review suggest an imperative for comprehensive interventions that address both intrinsic and extrinsic factors. Ultimately, the responsibility falls upon both the organizers and the pilgrims themselves to foster a safer environment. The Saudi government, in collaboration with international health organizations, can lead the way in



implementing recommendations, thereby honoring the sanctity of the pilgrimage and ensuring the safety of its participants.

## 5. Recommendations

To enhance the safety of pilgrims and minimize the risk of falls during the Hajj season, the following recommendations are proposed for the Saudi government:

1. Infrastructure Improvements: Develop and maintain pathways and common areas to ensure they are even and free of tripping hazards. Implement non-slip surfaces in areas known to become slick, such as the Tawaf area around the Kaaba.
2. Crowd Management: Employ advanced crowd control techniques, possibly using real-time monitoring systems to prevent overcrowding and manage the flow of pilgrims effectively. Designate separate pathways for vulnerable groups, such as the elderly or disabled, to reduce exposure to dense crowds.
3. Medical Services Accessibility: Increase the number and visibility of medical stations and ensure they are strategically placed for easy access. Train additional medical personnel in fall risk management and quick response strategies.
4. Pilgrim Education: Provide information on fall risks and prevention to pilgrims before arrival and upon their entry to Saudi Arabia. Educate pilgrims on the importance of hydration, rest, and self-monitoring for signs of heat exhaustion or other health issues.
5. Assistive Devices and Support: Offer rental services for mobility aids, such as wheelchairs, for those who may need them. Establish a volunteer corps to assist pilgrims who are at higher risk of falls.
6. Pilgrimage Preparation Programs: Develop pre-Hajj training programs that can help pilgrims, especially the elderly, to physically prepare for the demands of the pilgrimage.
7. Regulatory Measures: Enforce regulations on the quality and safety of temporary accommodations and facilities in Mina and Arafat. Require the use of sturdy, non-slip mats in tents and communal areas.

## References

- Al-Harhi, A. S., & Al-Harbi, M. (2001). Accidental injuries during muslim pilgrimage. *Saudi Med J*, 22(6), 523-525.
- Al-Hayani, M. M., Kamel, S., Al-Hayani, A. M., Al-Hazmi, E. A., Al-Shanbari, M. S., Al-Otaibi, N. S., Almeshal, A. S., & Assiri, A. M. (2023). Trauma and Injuries Pattern During Hajj, 1443 (2022): A Cross-Sectional Study. *Cureus*, 15(7), e41751. <https://doi.org/10.7759/cureus.41751>
- Alfelali, M., Barasheed, O., Alshehri, J., Bokhary, H., Alsaedi, S., Alhamzi, A., Aljohani, N., Driscoll, T., & Rashid, H. (2014). Foot Injuries Among Hajj Pilgrims with and Without Diabetes Mellitus: Implications for Infection Management. *Infect Disord Drug Targets*, 14(2), 140-147. <https://doi.org/10.2174/1871526514666140713160413>
- Alshehri, M. A., Alzaidi, J., Alasmari, S., Alfaqeh, A., Arif, M., Alotaiby, S. F., & Alzahrani, H. (2021). The Prevalence and Factors Associated with Musculoskeletal Pain Among Pilgrims During the Hajj. *J Pain Res*, 14, 369-380. <https://doi.org/10.2147/jpr.S293338>
- Bergen, G., Stevens, M. R., & Burns, E. R. (2016). Falls and Fall Injuries Among Adults Aged ≥65 Years - United States, 2014. *MMWR Morb Mortal Wkly Rep*, 65(37), 993-998. <https://doi.org/10.15585/mmwr.mm6537a2>
- Biju, K., Oh, E., Rosenberg, P., Xue, Q. L., Dash, P., Burhanullah, M. H., & Agrawal, Y. (2022). Vestibular Function Predicts Balance and Fall Risk in Patients with Alzheimer's Disease. *J Alzheimers Dis*, 86(3), 1159-1168. <https://doi.org/10.3233/jad-215366>

- Brenton-Rule, A., Dalbeth, N., Bassett, S., Menz, H. B., & Rome, K. (2015). The incidence and risk factors for falls in adults with rheumatoid arthritis: a systematic review. *Semin Arthritis Rheum*, 44(4), 389-398. <https://doi.org/10.1016/j.semarthrit.2014.08.001>
- Cameron, M. H., & Nilsagard, Y. (2018). Balance, gait, and falls in multiple sclerosis. *Handb Clin Neurol*, 159, 237-250. <https://doi.org/10.1016/b978-0-444-63916-5.00015-x>
- Dhital, A., Pey, T., & Stanford, M. R. (2010). Visual loss and falls: a review. *Eye (Lond)*, 24(9), 1437-1446. <https://doi.org/10.1038/eye.2010.60>
- Dunlop, D. D., Manheim, L. M., Sohn, M. W., Liu, X., & Chang, R. W. (2002). Incidence of functional limitation in older adults: the impact of gender, race, and chronic conditions. *Arch Phys Med Rehabil*, 83(7), 964-971. <https://doi.org/10.1053/apmr.2002.32817>
- Gaddoury, M. A., & Armenian, H. K. (2023). Epidemiology of Hajj pilgrimage mortality: Analysis for potential intervention. *J Infect Public Health*. <https://doi.org/10.1016/j.jiph.2023.05.021>
- Gazibara, T., Kurtagic, I., Kistic-Tepavcevic, D., Nurkovic, S., Kovacevic, N., Gazibara, T., & Pekmezovic, T. (2017). Falls, risk factors and fear of falling among persons older than 65 years of age. *Psychogeriatrics*, 17(4), 215-223. <https://doi.org/10.1111/psyg.12217>
- Granacher, U., Gollhofer, A., Hortobágyi, T., Kressig, R. W., & Muehlbauer, T. (2013). The importance of trunk muscle strength for balance, functional performance, and fall prevention in seniors: a systematic review. *Sports Med*, 43(7), 627-641. <https://doi.org/10.1007/s40279-013-0041-1>
- Hausdorff, J. M., Rios, D. A., & Edelberg, H. K. (2001). Gait variability and fall risk in community-living older adults: a 1-year prospective study. *Arch Phys Med Rehabil*, 82(8), 1050-1056. <https://doi.org/10.1053/apmr.2001.24893>
- Iinattiniemi, S., Jokelainen, J., & Luukinen, H. (2009). Falls risk among a very old home-dwelling population. *Scand J Prim Health Care*, 27(1), 25-30. <https://doi.org/10.1080/02813430802588683>
- Kelsey, J. L., Procter-Gray, E., Hannan, M. T., & Li, W. (2012). Heterogeneity of falls among older adults: implications for public health prevention. *Am J Public Health*, 102(11), 2149-2156. <https://doi.org/10.2105/ajph.2012.300677>
- Khan, I. D., Khan, S. A., Asima, B., Hussaini, S. B., Zakiuddin, M., & Faisal, F. A. (2018). Morbidity and mortality amongst Indian Hajj pilgrims: A 3-year experience of Indian Hajj medical mission in mass-gathering medicine. *J Infect Public Health*, 11(2), 165-170. <https://doi.org/10.1016/j.jiph.2017.06.004>
- Lee, J. W., Kang, S. H., & Choi, H. G. (2021). Analysis of the Associations between Arthritis and Fall Histories in Korean Adults. *Int J Environ Res Public Health*, 18(7). <https://doi.org/10.3390/ijerph18073758>
- Li, W., Keegan, T. H., Sternfeld, B., Sidney, S., Quesenberry, C. P., Jr., & Kelsey, J. L. (2006). Outdoor falls among middle-aged and older adults: a neglected public health problem. *Am J Public Health*, 96(7), 1192-1200. <https://doi.org/10.2105/ajph.2005.083055>
- Li, W., Procter-Gray, E., Lipsitz, L. A., Leveille, S. G., Hackman, H., Biondillo, M., & Hannan, M. T. (2014). Utilitarian walking, neighborhood environment, and risk of outdoor falls among older adults. *Am J Public Health*, 104(9), e30-37. <https://doi.org/10.2105/ajph.2014.302104>
- Manlapaz, D. G., Sole, G., Jayakaran, P., & Chapple, C. M. (2019). Risk Factors for Falls in Adults with Knee Osteoarthritis: A Systematic Review. *Pm r*, 11(7), 745-757. <https://doi.org/10.1002/pmrj.12066>
- McMurdo, M. E., & Gaskell, A. (1991). Dark adaptation and falls in the elderly. *Gerontology*, 37(4), 221-224. <https://doi.org/10.1159/000213264>

- Memish, Z. A., Steffen, R., White, P., Dar, O., Azhar, E. I., Sharma, A., & Zumla, A. (2019). Mass gatherings medicine: public health issues arising from mass gathering religious and sporting events. *Lancet*, 393(10185), 2073-2084. [https://doi.org/10.1016/s0140-6736\(19\)30501-x](https://doi.org/10.1016/s0140-6736(19)30501-x)
- Montero-Odasso, M., Verghese, J., Beauchet, O., & Hausdorff, J. M. (2012). Gait and cognition: a complementary approach to understanding brain function and the risk of falling. *J Am Geriatr Soc*, 60(11), 2127-2136. <https://doi.org/10.1111/j.1532-5415.2012.04209.x>
- Moreland, J. D., Richardson, J. A., Goldsmith, C. H., & Clase, C. M. (2004). Muscle weakness and falls in older adults: a systematic review and meta-analysis. *J Am Geriatr Soc*, 52(7), 1121-1129. <https://doi.org/10.1111/j.1532-5415.2004.52310.x>
- Naruse, M., Trappe, S., & Trappe, T. A. (2023). Human skeletal muscle-specific atrophy with aging: a comprehensive review. *J Appl Physiol* (1985), 134(4), 900-914. <https://doi.org/10.1152/jappphysiol.00768.2022>
- Nusbaum, N. J. (1999). Aging and sensory senescence. *South Med J*, 92(3), 267-275. <https://doi.org/10.1097/00007611-199903000-00002>
- Onofrei, R. R., & Amaricai, E. (2022). Postural Balance in Relation with Vision and Physical Activity in Healthy Young Adults. *Int J Environ Res Public Health*, 19(9). <https://doi.org/10.3390/ijerph19095021>
- Owaidah, A., Oлару, D., Bennamoun, M., Sohel, F., & Khan, N. (2023). Transport of pilgrims during Hajj: Evidence from a discrete event simulation study. *PLoS ONE*, 18(6), e0286460. <https://doi.org/10.1371/journal.pone.0286460>
- Park, S. H. (2018). Tools for assessing fall risk in the elderly: a systematic review and meta-analysis. *Aging Clin Exp Res*, 30(1), 1-16. <https://doi.org/10.1007/s40520-017-0749-0>
- Pirker, W., & Katzenschlager, R. (2017). Gait disorders in adults and the elderly : A clinical guide. *Wien Klin Wochenschr*, 129(3-4), 81-95. <https://doi.org/10.1007/s00508-016-1096-4>
- Razavi, S., Ardakani, H. Z., Rajai, S., Hollisaz, M., Sadeghipoor, H., Farshad, A., Shojaeezadeh, D., & Khodai, G. (2011). Trends in Prevalent Injuries among Iranian Pilgrims in Hajj. *Iran J Public Health*, 40(2), 110-115 .
- Rodrigues, F., Domingos, C., Monteiro, D., & Morouço, P. (2022). A Review on Aging, Sarcopenia, Falls, and Resistance Training in Community-Dwelling Older Adults. *Int J Environ Res Public Health*, 19(2). <https://doi.org/10.3390/ijerph19020874>
- Sanders, N. A., Ganguly, J. A., Jetter, T. L., Daccarett, M., Wasmund, S. L., Brignole, M., & Hamdan, M. H. (2012). Atrial fibrillation: an independent risk factor for nonaccidental falls in older patients. *Pacing Clin Electrophysiol*, 35(8), 973-979. <https://doi.org/10.1111/j.1540-8159.2012.03443.x>
- Sartini, M., Cristina, M. L., Spagnolo, A. M., Cremonesi, P., Costaguta, C., Monacelli, F., Garau, J., & Odetti, P. (2010). The epidemiology of domestic injurious falls in a community dwelling elderly population: an outgrowing economic burden. *Eur J Public Health*, 20(5), 604-606. <https://doi.org/10.1093/eurpub/ckp165>
- Tinetti, M. E. (2003). Clinical practice. Preventing falls in elderly persons. *N Engl J Med*, 348(1), 42-49. <https://doi.org/10.1056/NEJMc020719>
- Vaishya, R., & Vaish, A. (2020). Falls in Older Adults are Serious. *Indian J Orthop*, 54(1), 69-74. <https://doi.org/10.1007/s43465-019-00037-x>
- Wright, S. L., Kay, R. E., Avery, E. T., Giordani, B., & Alexander, N. B. (2011). The impact of depression on dual tasking among patients with high fall risk. *J Geriatr Psychiatry Neurol*, 24(3), 142-150. <https://doi.org/10.1177/0891988711409408> .



## Integrating Physical Therapy in Health Service Provision During Hajj Season: A Literature Review

Mohammed Saeed Alghamdi

Department of Medical Rehabilitation Sciences, Faculty of Applied Medical Sciences, Umm Al-Qura University

\*Corresponding author: E-mail (msgghamdi@uqu.edu.sa)

### دمج العلاج الطبيعي في تقديم خدمات الرعاية الصحية خلال موسم الحج: مراجعة أدبية

محمد سعيد الغامدي

قسم علوم التأهيل الطبي، كلية العلوم الطبية التطبيقية، جامعة أم القرى

#### الملخص

الهدف: تهدف هذه المراجعة الأدبية إلى استكشاف الدور المحتمل للعلاج الطبيعي خلال موسم الحج. المنهجية: تم إجراء مراجعة للأدبيات الحالية، تشمل دراسات حول العلاج الطبيعي في مختلف إعدادات الممارسة لإبلاغ تكامله ضمن الخدمات الصحية خلال موسم الحج. تم البحث في ثلاث قواعد بيانات رئيسية: Scopus, Web of Science, and MEDLINE عبر PubMed. النتائج: تم تضمين عدد 30 دراسة في هذه المراجعة. ظهرت أربعة مواضيع رئيسية من الدراسات وتسلط الضوء على أهمية العلاج الطبيعي في بيئات الممارسة ذات الصلة بالرعاية الصحية خلال موسم الحج: (1) فعالية العلاج الطبيعي في قسم الطوارئ، (2) فوائد دمج العلاج الطبيعي في الرعاية الصحية الأولية والوصول المباشر، (3) مخرجات المرضى ورضاهم، (4) ممارسو العلاج الطبيعي المتقدمين. كان العلاج الطبيعي في أقسام الطوارئ فعالاً بشكل ملحوظ في تحسين سير العمل، تقليل الحاجة إلى الأدوية وتقليل التنويم. الخلاصة: يلعب العلاج الطبيعي دوراً محورياً في تعزيز توفير الرعاية الصحية خلال موسم الحج. إن تكامله ضمن الفرق الطبية وخاصة في أقسام الطوارئ والرعاية الحرجة أمر ضروري لمواجهة التحديات الصحية الفريدة التي تواجه الحجاج. بناء على نتائج المراجعة، يدعو الباحث إلى توظيف أخصائيي العلاج الطبيعي ذوي التدريب العالي في موسم الحج وإلى مزيد من البحث العلمي لتحسين خدمات الرعاية الصحية خلال موسم الحج ومن ضمنها العلاج الطبيعي.

الكلمات الدالة: موسم الحج، العلاج الطبيعي، دمج الرعاية الصحية، صحة الحجاج.

#### Abstract

**Objective:** This literature review explores the potential role of physical therapy during the Hajj season.

**Methods:** A review of existing literature encompassing studies on physical therapy in different practice settings was conducted to inform its integration within healthcare services during the Hajj season. Three major databases were searched: Scopus, Web of Science, and MEDLINE via PubMed.

**Results:** A total of 30 studies were included in this review. Four key themes emerged from the studies highlighting the importance of physical therapy in practice settings relevant to healthcare during Hajj season: 1) effectiveness of physical therapy in emergency departments and acute care, 2) benefits of integrating physical therapy in primary health care and

direct access settings, 3) and patient outcomes and patient satisfaction, and 4) advanced practice physical Therapists. Physical therapy in emergency departments was notably effective in emergency departments, contributing to improved workflow, fewer medications prescribed, and reduced hospital admissions.

**Conclusion:** Physical therapy is pivotal in enhancing healthcare provision during the Hajj season. Its integration into medical teams, especially in emergency and acute care settings, is essential for addressing the unique health challenges of pilgrims. The review advocates for deploying highly trained physical therapists and calls for further research to optimize healthcare services during Hajj season, including physical therapy.

**Keywords:** Hajj season, physical therapy, healthcare integration, and pilgrim health.

## 1. Introduction

Mass gathering medicine is an emerging field that studies large-scale events' health effects and risks (1, 2). The Hajj, an annual Islamic pilgrimage to Makkah, is one of the largest mass gatherings in the world. The Hajj pilgrimage is a prime model for mass gathering medicine and presents a unique context for public health research (3-5). A notable study by Sweileh et al. (6) conducted a bibliometric analysis of literature from 1980 to 2020, focusing on health-related research during Muslim mass gatherings, especially the Hajj. This analysis identified four primary themes: 1) pilgrims' knowledge, attitudes, and practices; 2) vaccine-preventable outbreaks like meningitis and pneumonia; 3) patterns and causes of hospital admissions among pilgrims; and 4) the prevention and epidemiology of viral infectious diseases. These findings highlight the critical importance of health education, disease prevention, and healthcare planning for the Hajj season, considering its unique challenges and the vast number of participants.

Health risks during Hajj season are a significant concern due to the large number of pilgrims, the challenging conditions, and the potential for spreading diseases (5). Health conditions associated with Hajj season can be categorized into communicable diseases (e.g. meningococcal disease, respiratory tract infection), non-communicable diseases (cardiovascular diseases, arthritis), and injuries (trauma and falls, heat injuries) (4). Pilgrims with non-communicable diseases are at risk during Hajj due to crowded environments, limited access to healthcare, and inadequate preventive care (4, 5, 7). Injuries and trauma are prevalent among Hajj pilgrims, with a range of causes including falling, crowd-related incidents, road traffic accidents, and heat stroke (8-12). Alshehri et al. (13) conducted during the Hajj season to explore falls and musculoskeletal pain among pilgrims. In this study, 13.76% of sample reported falls and was higher in females. Additionally, 80.46% reported general musculoskeletal pain (pain at any site), particularly in the lower limbs. The Hajj pilgrimage is physically demanding as pilgrims generally walk long distances, potentially contributing to the risk of musculoskeletal pain (13). The insights from existing research offer important guidance for creating effective preventative programs and strategically allocating resources to address health concerns during the Hajj season.

Saudi Arabia offers free comprehensive healthcare services to pilgrims during the Hajj season, including surgeries, inpatient care, and vaccines through a network of specialized hospitals and health centres (14, 15). During Hajj season, the Ministry of Health (MOH) deploys a large number of health practitioners and medical resources to serve the pilgrims (16). For example, the General Authority for Statistics reported the deployment of over 31,571 healthcare providers in various settings in Makkah and the surrounding holy places during the 1439 H Hajj season (17). The medical infrastructure includes hospitals, primary care centers, emergency services, and virtual care (16, 17).

Physical therapy, a key allied health professions, plays a vital role in addressing diverse health issues (18). Traditionally, physical therapists have provided care in settings such as hospitals, rehabilitation centers, and home health environments

(18). In the last two decade, there has been a significant push to promote the inclusion of physical therapy into various new practice settings such as primary care (19) and emergency departments (20). The relevance physical therapy becomes particularly pronounced in the context of Hajj, where pilgrims encounter various physical challenges that increase the risk of musculoskeletal injuries (13). Despite its apparent significance, there is a notable lack of literature specifically addressing the role of physical therapy during Hajj season. This highlights the need for a comprehensive review of the available literature on the role of physical therapy in various practice settings to elucidate the contributions of physical therapy to the healthcare of pilgrims. Therefore, the aim of this review is to explore the potential role of physical therapy during Hajj season. Findings of this review could inform policymaking, guide research, and refining practice in this unique context.

## 2. Methodology (Materials and methods)

This study employed a literature review design. The literature search was conducted using the following databases: Scopus, Web of Science, and MEDLINE via PubMed. The search strategy involved a combination of keywords such as "Hajj," "mass gatherings," "rehabilitation or physical therapy," "healthcare services," "service delivery," and "practice or care setting." The inclusion criteria for selecting studies were: 1) physical therapy practice settings relevant to mass gatherings (direct access/primary care, emergency department, and acute care); 2) publication in English; and 3) no date restriction for the published material or study design. The search was done between August and December of 2023.

Studies were initially screened for relevance based on their titles and abstracts. Relevant studies underwent a full-text review to assess their suitability based on the inclusion criteria. Data extraction involved summarizing critical information from each study, including the study's aim, outcomes measured, and main findings. This data was then analyzed to identify common themes in the literature. The analysis aimed to synthesize the findings to provide a comprehensive understanding of the role of physical therapy in different practice settings and create recommendations for the integration of physical therapy during the Hajj season.

## 3. Results and Discussion

The search yielded a total of 30 studies focusing role of physical therapy in practice settings relevant mass gatherings as follows: direct access and primary care settings (n=11), emergency department (n= 9), and acute care setting (n=6). In addition, advance qualification of physical therapists emerged during the literature search and was relevant to the focus of the study (n= 4). Narrative summary of findings from studies for each practice setting is presented. Thematic analysis of literature revealed four main themes and are presented in Figure 1.

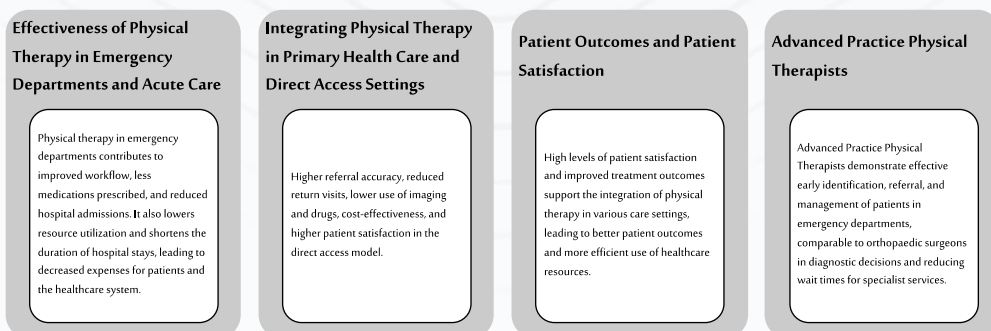


Figure 1. Main themes emerged from literature on physical therapy in different practice settings.

### ***Direct Access and Primary Care Settings***

Direct access to physical therapy in primary care settings has been extensively studied, revealing significant benefits and some challenges. The integration of physical therapy into primary healthcare is shown to offer early, cost-effective access, but it also requires specialized therapists and infrastructure (19, 21). In private healthcare, direct access is more prevalent and supported largely by education and associations; however, it faces less endorsement from policymakers and physicians (22). Reviews of both civilian and military health systems in the United States have supported the role of physical therapists in initial contact positions due to their safety, satisfaction, access, efficiency, and cost savings, despite facing challenges such as access restrictions and lack of privileges in civilian settings (23). There's also a notable shift in referral patterns, with an observed decline in referrals from primary care physicians to physical therapists for musculoskeletal conditions (24).

Direct access models are superior in referral accuracy, reduced return visits, lower imaging and drug use, cost-effectiveness, and patient satisfaction compared to physician-led models (25). Studies from the United States indicate that unrestricted access to physical therapy services leads to lower healthcare utilization and costs (26). In a systematic reviews and meta-analyses(27), findings highlight that direct access results in reduced costs, fewer visits, and greater functional improvement in comparison to systems requiring physician referrals. In the Netherlands, it has been observed that patients with direct access to physical therapy tend to receive fewer treatment sessions, without an increase in overall visits to therapists (28). The safety of direct access has been demonstrated in a university health center setting, where no adverse events or disciplinary actions were reported against physical therapists over a decade(29). Additionally, the role of primary contact physiotherapists in significantly reducing waiting and treatment times in emergency departments has been documented (30). These findings collectively emphasize the efficiency, cost-effectiveness, and patient satisfaction associated with direct access to physical therapy while highlighting its safety and reduced healthcare utilization. Supplementary Table 1 summarizes studies related to direct access to physical therapy and physical therapy in primary care settings.

### ***Emergency Departments***

The integration of physical therapy in emergency department settings has been increasingly recognized for its substantial positive impacts. Direct-access physical therapy for musculoskeletal disorders has been shown to improve clinical outcomes and reduce resource use in emergency departments (31). The combination of physical therapy with case management has a significant impact on reducing hospital admissions and costs (32). The benefits of emergency department-initiated physical therapy, including enhanced functional improvements for acute low back pain and reduced usage of high-risk medications, have been highlighted in multiple studies (20, 33). The role of physical therapists as musculoskeletal specialists in enhancing patient recovery is well advocated (34), and their services have been noted to significantly lower the likelihood of fall-related revisits for older adults (35). Early physical therapy after an emergency department visit for low back pain has been observed to reduce the risk of lumbar surgery and healthcare costs (36).

The effectiveness of physical therapy in pain and disability reduction has been reported to be comparable or superior to usual care (37). Physical therapy in emergency departments has also been linked with lower rates of imaging, opioid administration, and shorter stays, especially for patients with low back pain (38).

These studies collectively highlight the critical role of physical therapy in emergency departments in enhancing clinical outcomes, cost-effectiveness, and overall patient care. Supplementary Table 2 summarizes studies related physical therapy in emergency departments.

### **Acute Care Settings**

The role of physical therapy in acute care settings has been increasingly emphasized in a number of studies. A focus on functional activity in patient management across healthcare facilities has been highlighted, although practices vary widely (39). A qualitative study investigating the role of physical therapy in acute care settings uncovered key themes, including the utilization of specialized knowledge and the importance of effective communication. (40). In the context of intensive care unit (ICU), extended physical therapy was observed not to significantly improve physical function compared to standard care, but some positive trends were evident (41). The Harris 2014 study further reinforces the importance of early mobilization in ICU settings, showing increased physical therapy evaluations and improved interdisciplinary collaboration as key outcomes (42). The critical yet underutilized role of physical therapists in facilitating care transitions for older adults has been pointed out (43). Additionally, the integration of physical therapy into acute and emergency care has been supported for its high patient satisfaction and better treatment outcomes (44). These studies collectively highlight the significant and evolving impact of physical therapy in acute care settings, indicating its vital role in enhancing patient care and outcomes. Supplementary Table 3 summarizes studies related to physical therapy in acute care settings.

### **Advance Qualification of Physical Therapists (Advanced Practice Physical Therapists)**

Advanced Practice Physical Therapists (APPs), defined as therapists with specialized competencies attained through advanced training and education beyond foundational levels (45), have shown significant enhancements in clinical outcomes and patient satisfaction. For example, the effectiveness of APPs in reducing the diagnosis time for Axial Spondyloarthritis, significantly surpassing the UK average has been demonstrated(46). In the context of post-operative care for hip or knee replacements, APP-led clinics have been found to elicit high patient satisfaction, comparable to that of surgeon-led clinics, indicating no significant differences between the two (47). A similar safety profile between advanced practice physical therapy and primary care has been reported, with advanced practice physical therapy showing fewer safety events, less frequent use of diagnostic imaging and referrals, and comparable rates of minor harm events (48). Additionally, the proficiency of APPs in diagnosing and appropriately triaging musculoskeletal disorders has been highlighted, offering outcomes comparable to those of orthopedic surgeons and enhancing access to care(45). These findings collectively emphasize the potential and effectiveness of advanced physical therapy practice in improving healthcare delivery. Table 4 summarizes studies related to advance qualification of physical therapists (Advanced Practice Physical Therapists)

## **4. Conclusions**

This review highlights the essential role of physical therapy in improving healthcare during Hajj season, particularly in emergency and primary care settings. The integration of physical therapy not only enhances functional outcomes for pilgrims but also contributes to the overall efficiency and cost-effectiveness of healthcare services. In emergency departments, the presence of physical therapists has shown marked benefits in managing musculoskeletal issues commonly reported during Hajj. This may be beneficial in reducing the need for high-risk medications and hospital admissions. Given the demanding nature of Hajj pilgrimage, physical therapy significantly aids in alleviating injuries and pain among pilgrims, thus improving their experience. The insights from Lentz and colleagues' study (49) highlight the importance of aligning physical therapy practices with value-based care principles, redefining clinical decision-making to prevent unnecessary treatments, and expanding the scope of care beyond traditional areas. It emphasizes the necessity



for trained therapists to have a deep understanding of value-based care models, especially in acute care and emergency settings where quick, efficient, and expert care is crucial during the Hajj season.

It is important to note that Hajj season poses unique healthcare challenges, necessitating the training of therapists beyond the foundational level. Their specialized skills are particularly crucial in acute care and emergency settings, where timely and expert care is essential. Therefore, deploying well-trained physiotherapists could greatly enhance the effectiveness of medical teams during Hajj. Finally, this review advocates for increased recognition of physical therapy's role in mass gatherings such as Hajj pilgrimages and suggests further research and policy development to optimize its integration for better health outcomes.

## 5. Recommendations

Integrating physical therapy during Hajj season is important, given the physical demands and potential health risks associated with the pilgrimage. Based on the thematic analysis of physical therapy in various healthcare settings, I provide the following recommendations:

1. **Establishment of Physical Therapy Stations:** Dedicated physical therapy stations along the pilgrimage route, particularly in key areas such as the Holy Mosque, Mina, Arafat, and Muzdalifah, are proposed. It is imperative that these stations be equipped with the necessary tools and staffed by qualified physical therapists.
2. **Preventive and Educational Programs:** Educational sessions aimed at preventing musculoskeletal injuries are recommended before and during Hajj. The distribution of educational materials in various languages emphasizing the significance of physical wellness during Hajj is advocated.
3. **Direct Access for Pilgrims:** It is recommended to permit direct access to physical therapy services without necessitating a doctor's referral, thus expediting treatment for pilgrims with musculoskeletal injuries commonly seen by physical therapists.
4. **Mobile Physical Therapy Units:** The inclusion of physical therapists within medical teams stationed at key areas such as the Holy Mosque, Mina, Arafat, and Muzdalifah is recommended. Their presence would facilitate immediate care for musculoskeletal injuries, thereby alleviating the load on medical facilities. The deployment of mobile physical therapy units capable of reaching pilgrims in remote locations or those unable to travel to fixed stations is recommended.
5. **Training of Therapists:** Training of therapists, especially those in acute care and emergency departments, is important to ensure the safety of patients and the accurate identification of serious medical conditions for referral.
6. **Telehealth Services:** The employment of telehealth services for providing remote consultations and guidance, particularly beneficial for pilgrims with pre-existing conditions, is recommended.
7. **Collaboration with Emergency Services:** Collaboration with emergency medical services is essential for integrated care in cases of conditions relevant to physical therapy practice, such as musculoskeletal injuries.
8. **Research and Continuous Improvement:** Empirical research on the delivery of physical therapy services during the Hajj season is essential. Future research efforts are warranted to conduct empirical (primary) studies that aim to understand and improve the effectiveness of physical therapy and address the challenges encountered in this unique setting. For example, retrospective studies utilizing the clinical data available in hospitals serving pilgrims can be instrumental in exploring the characteristics of physical therapy services provided to pilgrims in previous Hajj seasons and drawing implications for future improvement.

## References

1. Memish ZA, Stephens GM, Steffen R, Ahmed QA. Emergence of medicine for mass gatherings: lessons from the Hajj. *The Lancet infectious diseases*. 2012;12(1):56-65.
2. Shafi S, Booy R, Haworth E, Rashid H, Memish ZA. Hajj: health lessons for mass gatherings. *Journal of infection and public health*. 2008;1(1):27-32.
3. Rahman J, Thu M, Arshad N, Van der Putten M. Mass gatherings and public health: case studies from the Hajj to Mecca. *Annals of global health*. 2017;83(2):386-93.
4. Aldossari M, Aljoudi A, Celentano D. Health issues in the Hajj pilgrimage: a literature review. *East Mediterr Health J*. 2019;25(10):744-53.
5. Ahmed QA, Arabi YM, Memish ZA. Health risks at the Hajj. *The Lancet*. 2006;367(9515):1008-15.
6. Sweileh WM. Health-related research publications on religious mass gatherings of Muslims: a bibliometric analysis (1980–2020). *Tropical Diseases, Travel Medicine and Vaccines*. 2022;8(1):1.
7. Shafi S, Dar O, Khan M, Khan M, Azhar EI, McCloskey B, et al. The annual Hajj pilgrimage—minimizing the risk of ill health in pilgrims from Europe and opportunity for driving the best prevention and health promotion guidelines. *Int J Infect Dis*. 2016;47:79-82.
8. Alfelali M, Barasheed O, Alshehri J, Bokhary H, Alsaedi S, Alhamzi A, et al. Foot injuries among hajj pilgrims with and without diabetes mellitus: implications for infection management. *Infectious Disorders-Drug Targets (Formerly Current Drug Targets-Infectious Disorders)*. 2014;14(2):140-7.
9. Al-Masud SMR, Bakar AA, Yusoff S. Determining the types of diseases and emergency issues in Pilgrims during Hajj: A literature review. *Stat Inf*. 2016;5(7)
10. Razavi S, Ardakani HZ, Rajai S, Hollisaz M, Sadeghipoor H, Farshad A, et al. Trends in prevalent injuries among Iranian pilgrims in Hajj. *Iranian journal of public health*. 2011;40(2):110.
11. Yezli S. Risk factors for heat-related illnesses during the Hajj mass gathering: an expert review. *Reviews on environmental health*. 2023;38(1):33-43.
12. Mehrvarz S, Bagheri MJ, Manoochehry S, Einollahi B, Ganjeh M, Doroudi T, et al. Evaluation of trauma management in injured Iranian Hajj pilgrims in 2015 Mina stampede. *Iranian Red Crescent Medical Journal*. 2021;23(3):6.
13. Alshehri MA, Alzaidi J, Alasmari S, Alfaqeh A, Arif M, Alotaiby SF, et al. The prevalence and factors associated with musculoskeletal pain among pilgrims during the Hajj. *Journal of Pain Research*. 2021:369-80.
14. Eltahir AHH. Development of health services in Hajj seasons. *Journal of family & community medicine*. 2000;7(1):13.
15. KSA's national source for government services and information: Healthcare During Hajj National Unified Portal; 2023 [Available from: <https://www.my.gov.sa/wps/portal/snp/aboutksa/HealthCareInKSA/?lang=en>].
16. Al-Shareef AS, Al-Thaqafy MS, Almalki AA, Alwael SS, Almetairi AM, Najmuldeen RF, et al. The role of emergency medical services providers during mass gathering: Hajj Season 2019. *Saudi Journal for Health Sciences*. 2022;11(1):17-22.
17. GASTAT. More Than 32,500 Employees Provide Medical and Health Services to Pilgrims in 1439 H Hajj Season: The General Authority for Statistics 2018 [Available from: <https://www.stats.gov.sa/en/news/272>].
18. APTA. APTA Guide to Physical Therapist Practice 4.0: American Physical Therapy Association 2023 [Available from: <https://guide.apta.org>].
19. Al-Abbad H, Madi S. Perception of tertiary care clients toward the availability of physical therapy service at primary health care centers in Saudi Arabia: A cross-sectional survey. *Journal of Physical Therapy Science*. 2020;32(5):323-31.
20. Kim HS, Strickland KJ, Mullen KA, Lebec MT. Physical therapy in the emergency department: a new opportunity for collaborative care. *The American Journal of Emergency Medicine*. 2018;36(8):1492-6.
21. Al-Abbad HM, Al-Haidary HM. The perception of physical therapy leaders in Saudi Arabia regarding physical therapy scope of practice in primary health care. *Journal of physical therapy science*. 2016;28(1):112-7.



41. Siesage K, Joelsson-Alm E, Schandl A, Karlsson E. Extended physiotherapy after Intensive Care Unit (ICU) stay: A prospective pilot study with a before and after design. *Physiotherapy Theory and Practice*. 2022;1-9.
42. Harris CL, Shahid S, editors. *Physical therapy—driven quality improvement to promote early mobility in the intensive care unit*. Baylor University Medical Center Proceedings; 2014: Taylor & Francis.
43. Falvey JR, Burke RE, Ridgeway KJ, Malone DJ, Forster JE, Stevens-Lapsley JE. Involvement of acute care physical therapists in care transitions for older adults following acute hospitalization: a cross-sectional national survey. *Journal of geriatric physical therapy* (2001). 2019;42(3):E73.
44. Skinner EH, Haines KJ, Berney S, Warrillow S, Harrold M, Denehy L. Usual care physiotherapy during acute hospitalization in subjects admitted to the ICU: an observational cohort study. *Respiratory care*. 2015;60(10):1476-85.
45. Vedanayagam M, Buzak M, Reid D, Saywell N. Advanced practice physiotherapists are effective in the management of musculoskeletal disorders: a systematic review of systematic reviews. *Physiotherapy*. 2021;113:116-30.
46. Hepburn J. Advanced practice physiotherapists in Scottish primary care: Axial Spondyloarthritis epidemiology, time to diagnosis, and referrals to rheumatology. *Musculoskeletal Care*. 2023.
47. Kennedy DM, Roberts S, Woodhouse L. Patients are satisfied with advanced practice physiotherapists in a role traditionally performed by orthopaedic surgeons. *Physiotherapy Canada*. 2010;62(4):298-305.
48. Mabry LM, Notestine JP, Moore JH, Bleakley CM, Taylor JB. Safety events and privilege utilization rates in advanced practice physical therapy compared to traditional primary care: an observational study. *Military Medicine*. 2020;185(1-2):e290-e7.
49. Lentz TA, Goode AP, Thigpen CA, George SZ. Value-based care for musculoskeletal pain: are physical therapists ready to deliver? *Physical therapy*. 2020;100(4):621-32.

Supplementary Table 1 summary of studies related direct access and primary care settings.

Study	Aim	Outcomes Measured	Main Findings
Al-Abbad & Madi (19)	To explore the views of physical therapy service leaders in Saudi Arabia on the provision of physical therapy service in primary health care (PHC) settings.	<ul style="list-style-type: none"> <li>- Views on the adoption of physical therapy services in PHC.</li> <li>- Perceived advantages and disadvantages of integrating physical therapy in PHC.</li> </ul>	<ul style="list-style-type: none"> <li>- Majority of participants believed integrating physical therapy in PHC would be advantageous, offering earlier access to health care and being more cost-effective.</li> <li>- Physical therapy in PHC was seen as beneficial for preventing non-communicable diseases and providing earlier access to care.</li> <li>- Challenges identified included the need for trained and specialized therapists, adequate infrastructure, and potential professional isolation.</li> </ul>
Al-Abbad & Al-Haidary (21)	To explore the views of physical therapy service leaders in Saudi Arabia on the provision of physical therapy service in PHC.	<ul style="list-style-type: none"> <li>- Perception of physical therapy leaders about the advantages of physical therapy services in PHC.</li> <li>- Potential challenges in integrating physical therapy into PHC.</li> </ul>	<ul style="list-style-type: none"> <li>- Majority (over 80%) reported physical therapy services in PHC as advantageous, with 85% agreeing it would reduce waiting times and costs.</li> <li>- Respondents highlighted the role of physical therapy in preventing common non-communicable diseases.</li> <li>- Disadvantages included the need for experienced therapists, infrastructure challenges, and possible lack of support from administrative and medical staff in PHC.</li> </ul>
Bury et al (22)	To map the presence of direct access to physical therapy services in WCPT member organizations, in the context of physical therapist practice and health systems.	Prevalence of direct access in various settings, education for direct access, support from associations and the public, and physical therapists' abilities in assessment, diagnosis, and referral.	58% reported direct access, more common in private settings. Education for direct access was available in 69% of countries. Support from national associations (89%) and the public (84%) was high, less so from policymakers (35%) and physicians (16%). Direct access linked with better abilities in assessment, diagnosis, and referral.
Clark et al (23)	To review the literature to identify the current state of direct access (DA) to physical therapy in the US and compare it with the US Military.	Literature review focusing on outcomes, autonomous practice, economic impact, and patient satisfaction related to direct access/self-referral/primary contact of physical therapists.	Support for PTs in an initial contact role based on safety, satisfaction, access, efficiency, and cost savings. US Military's success contrasts with limited civilian DA. Challenges include restrictions in DA and lack of privileges like ordering imaging or prescribing medications.
Freburger et al (24)	To examine trends in primary care physician (PCP) referral to physical therapy (PT) for musculoskeletal conditions and compare these to referrals to specialty physicians.	Trends in PT referral rates by PCPs for musculoskeletal-related visits.	Decline in PT referral rates between 2003 and 2014, with referral rates dropping over 50%. Increase in referrals to specialist physicians during the same period, indicating potential underuse or overuse of PT referrals.
Gallotti et al (25)	To compare the effectiveness, safety, and accuracy of direct access in physiotherapy (DAPT) with the physician-led model of care for musculoskeletal disorders.	Effectiveness, safety, accuracy, cost-effectiveness, patient satisfaction, and health outcomes of DAPT.	DAPT showed high referral accuracy, reduced return visits, lower use of imaging and drugs, cost-effectiveness, better work-related outcomes, and higher patient satisfaction. No difference in health outcomes compared to the medical model.
Garrity et al (26)	To evaluate the association between access to physical therapist services and low back pain (LBP)-related	Healthcare utilization and costs related to LBP in unrestricted and provisional direct access states.	In states with unrestricted access, healthcare utilization and costs related to short-term LBP were lower compared to states with provisional access.

Study	Aim	Outcomes Measured	Main Findings
	healthcare utilization and costs.		
Hon et al (27)	To assess the differences in costs and clinical results between systems where patients have direct access versus systems requiring a physician referral first in American civilian health services for musculoskeletal disorders.	Functional outcomes, physical therapy costs, total health care costs, and number of physical therapy visits.	Direct access to physical therapy showed reduced costs, fewer visits, and greater functional improvement than physician-first systems.
Leemrijse et al (28)	To investigate how many patients use direct access to physical therapy in the Netherlands and the characteristics of these patients.	Utilization of direct access by patients, number of treatment sessions, characteristics of patients using direct access.	Over quarter of patients seen by a physical therapist came via direct access. Patients with direct access received fewer treatment sessions. There was no increase in the number of patients visiting physical therapists within a year (2005-2006).
Mintken et al (29)	To determine if direct access to physical therapy in a university health center placed patients at risk for adverse events.	Patient adverse events and disciplinary or legal action against physical therapists.	Over a 10-year period, no serious medical pathology or adverse events were reported, and no physical therapists had their credentials or licenses modified or revoked for disciplinary action. The study concluded that patients managed through direct access are at minimal to no risk for negligent care
Bird et al (30)	To evaluate if primary contact physiotherapists can reduce waiting and treatment times in Australian emergency departments.	Waiting time, treatment time, time to discharge from the emergency department.	Patients treated by primary contact physiotherapists waited 31 minutes less and had shorter treatment times (108 vs 148 minutes). A higher proportion (93% vs 75%) were discharged within a 4-hour time period.

Supplementary Table 2 summary of studies related physical therapy in emergency department.

Study	Aim	Outcomes Measured	Main Findings
Gagnon et al (31)	To evaluate the effects of direct-access physiotherapy on patients with musculoskeletal disorders in the emergency department on clinical outcomes and healthcare resource use.	Clinical outcomes (pain, function) and resource use (ED return visits, medications, tests, consultations) in a randomized controlled trial.	Patients with direct access to a physiotherapist had better clinical outcomes and used fewer services and resources than the usual care group, both after ED discharge and up to 3 months later.
Gurley et al (32)	To evaluate the benefit of using ED-based physical therapist and case management services instead of routine hospital admission.	Physical therapy consultation outcomes in the ED, including hospital admission rates and discharge dispositions.	The implementation of physical therapy and case management systems based in emergency departments is an effective approach to significantly reduce hospital admissions and can potentially lower resource utilization, shorten the duration of hospital stays, and decrease expenses for both patients and the healthcare system.
Kim et al (20)	To describe the emergence and impact of emergency department-initiated physical	Clinical and operational outcomes, patient and physician satisfaction with ED PT services.	ED PT is an emerging resource, associated with improved clinical outcomes and high satisfaction among patients and physicians. ED PT contributes to improved workflow and patient care.

Study	Aim	Outcomes Measured	Main Findings
	therapy (ED PT) in the United States.		
Kim et al (33)	To compare patient-reported outcomes in patients receiving ED-initiated physical therapy and usual care for acute low back pain.	Pain-related functioning, use of high-risk medications, Oswestry Disability Index (ODI), and Patient-Reported Outcomes Measurement Information System pain interference (PROMIS-PI) scores.	ED-initiated physical therapy was correlated with enhanced functional improvements and reduced utilization of high-risk medications when compared to standard care.
Lebec et al (34)	To explore the rationale for utilizing physical therapists as musculoskeletal specialists in the emergency department (ED).	Narrative review to explore expertise of physical therapists in ED settings, improvement in patient management through integration of physical therapy.	Physical therapists have the knowledge and skills to provide expertise in musculoskeletal practice in the ED. Early access to physical therapy in the ED can positively influence patient recovery.
Lesser et al (35)	To determine whether providing physical therapy services in the emergency department improves outcomes for older adults who have fallen.	Recurrent fall-related emergency department revisit rates within 30 and 60 days.	Physical therapy services in the emergency department were associated with a significantly lower likelihood of a fall-related ED revisit within 30 and 60 days.
Magel et al (36)	To examine the association between the timing of physical therapy initiation after an emergency department visit for low back pain and subsequent healthcare utilization and costs.	Lumbar surgery, advanced imaging, long-term opioid use, and healthcare costs in the following 12 months.	Early physical therapy was associated with a reduced risk of lumbar surgery, advanced imaging, long-term opioid use, and incurred lower healthcare costs compared to delayed physical therapy.
Matifat et al (37)	To update evidence regarding physical therapist care for patients with musculoskeletal disorders in emergency departments (EDs) and to update recommendations for these models of care.	Effectiveness in pain reduction, disability reduction, waiting time in EDs, medical imaging orders, healthcare costs, and patient satisfaction.	Physical therapist care in EDs was as effective as or more effective than usual medical care in various aspects, including pain reduction, disability reduction, and waiting time. No significant differences were found in healthcare costs between physical therapist care and usual care in EDs
Pugh et al (38)	To assess the impact of emergency department physical therapy (ED-PT) on imaging studies, rates of opioids prescribed, and ED length of stay for musculoskeletal pain.	Imaging studies obtained, rates of opioids prescribed, and ED length of stay.	Patients who received PT had lower rates of imaging, ED opioid administration, and shorter average ED length of stay. In a subgroup analysis of low back pain patients, PT patients had fewer imaging studies but similar rates of opioid administration and average ED length of stay compared to non-PT patients.

Supplementary Table 3 summary of studies related acute care settings.

Study	Aim	Outcomes Measured	Main Findings
Jette et al (39)	To provide an overview of how physical therapists handle patient care within the acute	Patient management details across diagnoses and facilities, including	A predominant emphasis on functional activity in patient management. Notably, there was no discernible pattern observed regarding examinations, goals, and interventions

Study	Aim	Outcomes Measured	Main Findings
	care environment and analyze the differences in approaches among various healthcare facilities.	examinations, goals, and interventions.	tailored to specific diagnoses. Additionally, the study revealed a modest level of variability in practice among the surveyed facilities.
Masley et al (40)	To describe the role, clinical reasoning processes, and context of physical therapy services in the acute care setting.	Themes identified from interviews with physical therapists.	Eight themes were identified, including collection and analysis of medical information, application of specialized knowledge, communication, continual dynamic assessment, professional responsibility, complex environment, and decision making for patient care
Siesage et al (41)	To examine whether extended physiotherapy compared to standard level has beneficial effects on physical function in ICU survivors.	Physical function measured with the Chelsea Critical Care Physical Assessment tool at various stages	No statistically significant differences were found between the groups in physical function, hospital stay, and readmissions, but tendencies to better outcomes in all these parameters were observed in the intervention group. The intervention group had significantly higher scores in specific physical assessment items at hospital discharge.
Falvey et al (43)	This study aims to explore how physical therapists contribute to care transitions for older adults after hospital discharge, focusing on communication and implementation of care transition strategies.	The study quantifies the involvement of physical therapists in various care transition activities and identifies common practices and communication methods used.	The findings highlight that while physical therapists' involvement in care transitions is infrequent, their role can be crucial, particularly in identifying and communicating patient needs during transitions.
Skinner et al (44)	This study explores the benefits and outcomes of integrating physical therapy into acute and emergency care, with a focus on patient-centered care.	It assesses patient satisfaction, treatment efficacy, and overall health outcomes in acute care settings with integrated physical therapy services.	The findings indicate high levels of patient satisfaction and improved treatment outcomes, supporting the integration of physical therapy in acute and emergency care for enhanced patient care.
Harris et al (42)	Introduce a physical therapist-led program to promote early mobility in medical-surgical and cardiovascular ICUs. The initiative focused on changing the ICU culture by enhancing interdisciplinary communication and collaboration among physical therapists, nurses, respiratory therapists, and physicians	Interdisciplinary Meeting Effectiveness: Addressing barriers to early ICU mobilization. Barriers Identification: Understanding challenges such as patient illness severity, safety, time constraints, staff limits, and ICU cultural change.	Early mobilization in the ICU is a safe and cost-effective strategy to improve patient outcomes. Key barriers identified included concerns for safety with critically ill patients, staffing needs, the necessity of multidisciplinary collaboration, and the time required for mobilization, especially for patients on multiple lines. It was observed that educating and involving the critical care team in the process was crucial for the successful implementation of early mobility protocols

Supplementary Table 4 summary of studies related to advance qualification of physical therapists (Advanced Practice Physical Therapists)

Study	Aim	Outcomes Measured	Main Findings
Hepburn (46)	To evaluate a Musculoskeletal Advanced Practice Physiotherapist Service (APP) in Scottish Primary Care, focusing on Axial Spondyloarthritis (AxSpA).	Incidence and time to diagnosis of AxSpA, compliance with referral criteria, and referral conversion rates.	Mean time to diagnosis of AxSpA was 3.4 years with APP having shorter time to diagnosis than (5.1 year) than the UK average of 8.5 years, indicating effective early identification and referral by Advanced Practice Physiotherapy services.



Study	Aim	Outcomes Measured	Main Findings
Kennedy et al (47)	To assess and make a comparative analysis of patient satisfaction concerning post-operative care in clinics managed by advanced practice physiotherapists (APPs) and orthopedic surgeons following hip or knee replacement procedures.	Patient satisfaction using a modified satisfaction questionnaire.	Study found significant patient satisfaction with care in both APP-led and surgeon-led clinics, with no significant differences between them.
Mabry et al (48)	To examine the rate of safety events and utilization of services in an advanced practice physical therapy clinic compared to a primary care clinic.	Safety events, prescriptions, laboratory studies, imaging studies, referrals, and diagnoses.	Advanced practice physical therapy had a similar safety profile to primary care, with fewer safety events reaching patients, less frequent ordering of diagnostic imaging and referrals, and a similar rate of minor harm events.
Vedanayagam et al (45)	To evaluate whether advanced practitioner physiotherapists (APPs) are accurate at diagnosis, can triage appropriately, and improve patient treatment outcomes and access to care for musculoskeletal disorders.	Accuracy of diagnosis, triage appropriateness, patient treatment outcomes, access to care.	APPs are comparable to orthopaedic surgeons in diagnostic decisions, reduce wait times for specialist services, and can independently manage most patients in various clinical settings.



## The Impact of a Prolonged 12-Hour Shift for Consecutive 15 Days on Occupational Fatigue, Missed Nursing Care and Quality of Nursing Care Among Nurses During Hajj: A longitudinal Study

Faisal Alasmari<sup>1\*</sup>, Mohamed Shahid<sup>1</sup>, Rayan Omar Alzubaidi<sup>2</sup>, Mhasen Hawsawi<sup>2</sup>, Rawan Bukhari<sup>2</sup>, Wasayf Alhazmi<sup>2</sup>, Shoq Alhawass<sup>2</sup>, Laila Ibrahim<sup>2</sup>, Marwah Aljawi<sup>2</sup>, Rayan Siddiq<sup>2</sup>, Alanoud Alluqmani<sup>2</sup>, Maathir Mukhtar<sup>2</sup>, Hossam Alharbi<sup>2</sup>

1- Nursing Research and EBP Department, King Abdullah Medical City, 2- Neuro Intrnsive Care Unit, King Abdullah Medical City.

\*Corresponding author: E-mail (Alasmari.F@kamc.med.sa)

## تأثير العمل بنظام الورديات المطولة لمدة 12 ساعة في 15 يوماً متتالية على الإرهاق المهني وفقدان الرعاية وجودة الرعاية التمريضية المطلوبة بين الممرضين

### المخلص

الخلفية: تشكل الخدمات الصحية خلال الحج تحدياً فريداً للممرضين، حيث يتطلب العمل لمدة 12 ساعة متواصلة لمدة 15 يوماً متتالية. تقدم هذه الدراسة الرائدة تقييماً كمياً لتأثير هذا الجدول الزمني المجهد على الإرهاق الوظيفي للممرضين، والرعاية التمريضية المفقودة، وجودة الرعاية التمريضية في نقطتين حرجيتين. الطرق: تم استخدام تصميم طولي، حيث تم استطلاع آراء 306 من الممرضين في المدينة الطبية الملكية عبد الله. أكمل ما مجموعه 171 ممرضاً وممرضة التقييمات اللازمة باستخدام مقياس الإرهاق الوظيفي والتعافي (OFER)، واستطلاع MISSCARE للرعاية التمريضية المفقودة، ومقياس ليكرت لجودة الرعاية التمريضية في بداية فترة الحج ونهايتها. النتائج: كان هناك زيادة ذات دلالة إحصائية في المعدلات الوسطية للإرهاق الوظيفي (من 33.07 إلى 35.18) والرعاية التمريضية المفقودة (من 36.48 إلى 49.81)، وكذلك انخفاض في جودة الرعاية التمريضية المدركة (من 4.30 إلى 3.35) من بداية فترة الحج إلى نهايته.

الاستنتاجات: تسلط هذه الدراسة الضوء على التأثير الوظيفي الكبير الذي تحدثه الورديات المطولة على الممرضين خلال الحج. تؤكد الزيادات في النتائج السلبية من بداية إلى نهاية الحج على ضرورة إجراء مزيد من البحوث حول آثار العمل بنظام الورديات وتدعو إلى إعادة تقييم جداول عمل الممرضين لتحسين رفاهيتهم وجودة الرعاية الصحية للمرضى خلال الأحداث المجهدة.

الكلمات الدالة: الإرهاق الوظيفي، جودة الرعاية التمريضية، الرعاية التمريضية المفقودة، العمل بنظام الورديات، الدراسة الطولية، الحج، رفاهية الممرضين، جداول العمل، توظيف الكوادر الصحية، سلامة المرضى.

### Abstract

**Background:** Nursing during the Hajj pilgrimage involves extended 12-hour shifts for 15 consecutive days. This pioneering study quantifies the impact of this rigorous schedule on nurses' occupational fatigue, missed care, and care quality at two critical points. **Methods:** A longitudinal approach was employed, surveying 306 staff nurses from King Abdullah Medical City. A total of 171 nurses completed key assessments using the Occupational Fatigue Exhaustion

Recovery (OFER) scale, the MISSCARE Survey, and a Likert scale measuring the quality of nursing care at the onset and conclusion of the Hajj duty. **Results:** There was a statistically significant increase in the mean scores for occupational fatigue (from 33.07 to 35.18) and missed nursing care (from 36.48 to 49.81), as well as a decrease in the perceived quality of nursing care (from 4.30 to 3.35) from the beginning to the end of the Hajj period.

**Conclusions:** This study sheds light on the substantial occupational impact prolonged shifts have on nursing staff during the Hajj. The increases in negative outcomes from the start to the end of the Hajj emphasize the need for further research into the effects of shift work and call for a reevaluation of nurse work schedules to enhance their well-being and the overall quality of patient care during high-stress events.

**Keywords:** Occupational Fatigue, Nursing Care Quality, Missed Nursing Care, Shift Work, Longitudinal Study, Hajj, Nurse Well-being, Work Schedules, Healthcare Staffing, Patient Safety.

## 1. Introduction.

The Hajj is an annual Islamic pilgrimage to Mecca, Saudi Arabia, attracting millions of pilgrims from all over the world. Nurses play a crucial role in providing care to the pilgrims during Hajj (Ridda et al., 2021). These situations daily challenge nurses to incorporate the diverse needs of their patients into the provision of safe and quality nursing care, especially during the peak of the Hajj season (Ridda et al., 2021). One of the challenges faced by nurses during Hajj is working long hours for consecutive days. The Saudi Arabian Ministry of Health mandates that nurses work 12-hour shifts for 15 consecutive days during the Hajj period (Saleh et al., 2021). This prolonged 12-hour shift pattern has been associated with occupational fatigue, missed nursing care, and reduced quality of nursing care (Griffiths et al., 2014; Cockerham, Kang, & Beier, 2023). The main work system among Makkah nurses during the Hajj season involves working as full-time employees based on 12-hour shifts for continuous 15 days, which includes working from 7:00 a.m. to 7:00 p.m. (or 7:00 p.m. to 7:00 a.m.). This study represents the first of its kind to investigate the impact of prolonged 12-hour shifts for consecutive 15 days on occupational fatigue, missed nursing care, and quality of nursing care among nurses during Hajj. Understanding these effects can help inform policies and practices aimed at improving working conditions for nurses during this challenging event. The primary aim of this study is to investigate the effects of prolonged 12-hour shifts over a consecutive 15-day period on occupational fatigue, missed nursing care, and the quality of nursing care among nurses during Hajj by comparing measurements taken at two points: the first 5 days and the last 5 days of the Hajj period. A secondary aim is to examine the relationships between these factors at both time points to understand how occupational fatigue may lead to missed nursing care and how both may affect the quality of nursing care provided during this demanding time.

## 2. Methodology (Materials and methods)

### Research Design

The study adopts a longitudinal design, focusing on the effects of prolonged shifts on nurses at King Abdullah Medical City (KAMC) during Hajj. This approach allows for the assessment of changes over time, specifically comparing the first 5 days and last 5 days of the Hajj period.

### Population and Sampling

The study population included 306 staff nurses in critical care and cardiac care units at KAMC. A sample of 171 nurses was selected using convenient sampling. Inclusion criteria consisted of nurses working during Hajj and willing to participate, while those absent during data collection or not willing to participate were excluded.

### Study Procedure

Data was collected through two online surveys conducted at the beginning and end of the Hajj duty. Participant anonymity was maintained by using unique codes instead of names. Nurses were informed about the study's aim and procedures, and verbal consent was obtained. Participants can withdraw at any time without penalty.

### Data Collection Tool

The survey comprises four parts: socio-demographic details, fatigue assessment using the Occupational Fatigue Exhaustion Recovery (OFER) scale, missed nursing care measured by the MISSCARE Survey, and a self-assessment of nursing care quality. The OFER scale, the MISSCARE Survey, and the nursing care quality assessment all utilize a 5-point Likert scale, providing comprehensive data on various aspects of nursing work during Hajj.

### 3. Results and Discussion

Table (1): Mean differences of occupational fatigue and exhaustion recovery, missed nursing care and quality of nursing care among Nurses.

Variables	At the beginning of hajj duty	At the end period of hajj duty	t	Sig
	Mean±SD	Mean±SD		
1. Occupational Fatigue	33.07±5.36	35.18±5.38	4.21	0.000**
A. Chronic fatigue	17.01±3.52	18.73±3.89	4.69	0.000**
B. Acute fatigue	16.06±2.51	16.45±2.29	1.79	0.07
2. Missed Nursing Care	36.48±12.11	49.81±21.98	7.87	0.000**
3. Quality of Nursing Care	4.30±0.81	3.35±1.33	8.16	0.000**

The results of this study underscore the progressive increase in occupational fatigue among nurses, correlating with a significant rise in missed nursing care and a decline in the self-reported quality of nursing care over the course of the Hajj duty. The mean scores for occupational fatigue rose from 33.07 at the beginning to 35.18 at the end of Hajj, while missed care increased markedly from 36.48 to 49.81, and perceived care quality decreased from 4.30 to 3.35. These findings are supported by Griffiths et al. (2014), who reported similar deteriorations in patient safety and care quality with extended 12-hour shifts.

The study's observations are consistent with Cochran's (2021) findings, which linked acute fatigue to 12-hour shifts in specific units, and with Thompson's (2019) research highlighting the cumulative fatigue impairments from multiple compressed shifts. These consequences resonate with Geiger-Brown et al. (2012), who found that nurses accumulate sleep debt over successive shifts, leading to increased fatigue and sleepiness. Moreover, Cockerham, Kang, & Beier (2023) emphasize that such fatigue is particularly pronounced in night shift workers. The current study adds to the existing body of literature by confirming that fatigue levels indeed accumulate across consecutive shifts (Cho et al., 2021), suggesting that the scheduling of nursing shifts during demanding periods such as Hajj requires careful consideration to mitigate the potential negative impacts on both nurses and patient care.

Table (4): Relationship between quality of nursing care, occupational fatigue and missed nursing care at the beginning of hajj duty.

	Quality of nursing care	Occupational fatigue	Missed nursing care
▪ Quality of nursing care	1	0.01	-0.24**
▪ Occupational fatigue	0.01	1	0.18*
▪ Missed nursing care	-0.24**	0.18*	1

\* Statistically significant (p ≤0.05) \*\* Highly statistically significant (p ≤0.01)

Table (5): Relationship between quality of nursing care, occupational fatigue and missed nursing care at the end of hajj duty.

	Quality of nursing care	Occupational fatigue	Missed nursing care
▪ Quality of nursing care	1	-0.37**	-0.72**
▪ Occupational fatigue	-0.37**	1	0.41**
▪ Missed nursing care	-0.72**	0.41**	1

\* Statistically significant ( $p \leq 0.05$ ) \*\* Highly statistically significant ( $p \leq 0.01$ )

The study detailed in Tables 4 and 5 demonstrates significant changes in the relationship between nurses' fatigue, missed care, and the overall quality of care provided from the start to the end of Hajj duty.

The study's analysis of nurses working during Hajj reveals a concerning trend: as the 15-day period progresses, the negative effects of occupational fatigue on nursing care intensify. At the beginning, fatigue was minimally linked to missed care ( $r = 0.18$ ), and only slightly impacted the quality of care ( $r = -0.24$ ). Yet, by the end of Hajj, a strong negative correlation emerges between missed care and care quality ( $r = -0.72$ ), showing that as nurses skip more tasks, care quality significantly worsens. Similarly, the connection between fatigue and care quality also becomes stronger ( $r = -0.37$ ), indicating that tired nurses are more likely to provide lower quality care.

The findings also reveal that by the end of the Hajj, fatigue more strongly predicts missed care ( $r = 0.41$ ), suggesting that fatigue accumulates over time, increasingly affecting nurses' performance. This study corroborates findings from Min et al. (2021), who reported that higher fatigue levels result in more unfinished care tasks. The escalating relationship between fatigue and both missed care and decreased care quality calls attention to the pressing need for effective management of nurse fatigue to maintain optimal care during demanding periods like the Hajj.

#### 4. Conclusions

This study stands as the first of its kind to systematically evaluate the effects of prolonged 12-hour shifts over a consecutive 15-day period on nurses during the Hajj, measuring occupational fatigue, missed nursing care, and the quality of nursing care at two critical points. The results unambiguously show an escalation in occupational fatigue and missed care, accompanied by a decline in perceived care quality as the Hajj progresses. These findings are consistent with existing literature that highlights the challenges of extended work shifts in healthcare settings.

The significance of these results lies in their timing capturing the dynamics at the beginning and the end of the Hajj duty, thereby providing a clear depiction of the toll such demanding schedules take on nursing staff. This study is the first to monitor how nurses' work stress changes over a specific time during high-pressure situations. It lays the foundation for more research and helps us understand the challenges nurses face in stressful environments. By showing how fatigue increases over time and affects nurses and patient care, this research could start important conversations about how to improve nurses' work schedules to protect their health and maintain good patient care during big events like the Hajj.

#### 5. Recommendations

This study highlights the need for strategies to reduce nurse fatigue and improve patient care, especially during high-stress events like Hajj. Key recommendations include:

1. Shift Structure Modification: Adjust 12-hour shifts to include rest breaks and task rotation to lessen fatigue.
2. Optimizing Staffing: Increase staff during high-fatigue times to reduce workload and prevent missed care.
3. Mandatory Rest Periods: Implement required rest after shifts and support off-duty recovery.
4. Proactive Fatigue Management: Conduct regular check-ins and safety huddles when fatigue levels are high.

5. Scheduling for Recovery: Design work schedules that allow enough rest between shifts.
6. Education on Sleep Importance: Teach nurses about the critical role of sleep in job performance and safety.

#### References:

1. Cho, H., Brzozowski, S., Arsenault Knudsen, É. N., & Steege, L. M. (2021). Changes in Fatigue Levels and Sleep Measures of Hospital Nurses During Two 12-Hour Work Shifts. *JONA: The Journal of Nursing Administration*, 51(3), 128-134. <https://doi.org/10.1097/NNA.0000000000000983>
2. Cochran, K. R. (2021). An Examination of Work Characteristics, Fatigue, and Recovery Among Acute Care Nurses. *JONA: The Journal of Nursing Administration*, 51(2), 89-94. <https://doi.org/10.1097/NNA.0000000000000975>
3. Cockerham, M., Kang, D. H., & Beier, M. E. (2023). Consecutive Shifts: A Repeated Measure Study to Evaluate Stress, Biomarkers, Social Support, and Fatigue in Medical/Surgical Nurses. *Behavioral Sciences*, 13(7), 571. <https://doi.org/10.3390/bs13070571>
4. Geiger-Brown, J., Rogers, V. E., Trinkoff, A. M., Kane, R. L., Bausell, R. B., & Scharf, S. M. (2012). Sleep, Sleepiness, Fatigue, and Performance of 12-Hour-Shift Nurses. *Chronobiology International*, 29(2), 211–219. <https://doi.org/10.3109/07420528.2011.645752>
5. Griffiths, P., Dall’Ora, C., Simon, M., Ball, J., Lindqvist, R., Rafferty, A., Schoonhoven, L., Tishelman, C., & Aiken, L. (2014). Nurses’ Shift Length and Overtime Working in 12 European Countries. *Medical Care*, 52, 975 - 981. <https://doi.org/10.1097/MLR.0000000000000233>
6. Min, A., Kim, Y. M., Yoon, Y. S., Hong, H. C., Kang, M., & Scott, L. D. (2021). Effects of Work Environments and Occupational Fatigue on Care Left Undone in Rotating Shift Nurses. *Journal of Nursing Scholarship*, 53(1), 126-136. <https://doi.org/10.1111/jnu.12604>
7. Saleh, U. S., Jenkins, P., Saleh, B., Saleh, M., Abu Sammour, H., Tiking, D., & Abujoudeh, E. (2021). Nurses' compassion fatigue during the pilgrim (al-hajj) season. *Saudi Journal of Health Systems Research*, 1(2), 41-50.
8. Thompson, B. J. (2019). Does work-induced fatigue accumulate across three compressed 12 hour shifts in hospital nurses and aides?. *PLoS One*, 14(2), e0211715. <https://doi.org/10.1371/journal.pone.0211715>



## Integrating Health Belief and Social Ecological Models: A Strategic Proposed Framework for Health Promotion and Education Among Makkah's Pilgrims

Abdulhadi Al Ruwaithi<sup>1\*</sup>, Moiyad Aljehani<sup>2</sup>, Khalil Ismail<sup>3</sup> and Abdulrahman Almeahmadi<sup>3</sup>

1-Department of Clinical Technology, Umm Al-Qura University, 2- Department of Medical Rehabilitation Sciences, Umm Al-Qura University, 3-Department of Epidemiology and Medical Statistics, Umm Al-Qura University.

\*Corresponding author: E-mail (aaruwaithi@uqu.edu.sa)

## دمج نموذجي المعتقد الصحي و البيئي الاجتماعي: إطار استراتيجي مقترح لتصميم وتنفيذ برامج التوعية والتثقيف الصحي للحجاج والمعتمرين

عبد الهادي الرويثي<sup>1\*</sup>، مؤيد الجهني<sup>2</sup>، خليل اسماعيل<sup>3</sup>، عبدالرحمن المحمادي<sup>3</sup>

1- قسم التقنية السريرية، جامعة أم القرى، 2- قسم علوم التأهيل الطبي، جامعة أم القرى، 3- قسم الوبائيات والإحصاء الطبي، جامعة أم القرى.

### المخلص

هناك أهمية كبيرة لبرامج التوعية الصحية للحجاج والمعتمرين القادمين إلى مكة، حيث تُسهم هذه البرامج بشكل كبير في رفاهية وسلامة الأفراد الذين يؤدون المناسك، وخصوصاً حج البيت في مكة المكرمة. هناك نقص في الأبحاث الشاملة حول برامج التوعية الصحية والتعريفية للخدمات الصحية للمجموعات الخارجية أو المجتمعات الانتقالية مثل المهاجرين والحجاج والمسافرين. الهدف من هذه الورقة هو توضيح مكونات برنامج التوعية الصحية المناسب لمجتمع الحجيج في مكة المكرمة، والذي من الممكن أن يتم تقديمه للحجاج (زوار العمرة والحج) قبل مغادرتهم إلى المملكة العربية السعودية. استناداً إلى نموذج الاعتقاد الصحي (HBM) والنموذج البيئي الاجتماعي (SEM)، تحدد الورقة العناصر والخطوات الأساسية ضمن إطار نظري لتصميم برامج التوعية الصحية للحجاج الدوليين من خلفيات ثقافية متنوعة. بشكل مشابه ل SEM يشمل الإطار خمس مستويات رئيسية: الأفراد، العلاقات، المستوى المؤسسي، المستوى المجتمعي، السياسات والقوانين. من أهم العناصر المتضمنة في هذه المستويات الإرشادية هي المحاضرات التوعية حول مخاطر الصحة خلال الحج، والتعليم حول مزايا التدابير الوقائية، ومشاركة قادة الحملات الحجية والخطباء في نشر المعلومات الصحية بين أعضاء حملاتهم، والتدريب العملي حول إجراءات مكافحة العدوى والاسعافات الأساسية. تنفذ هذه العناصر بشكل أساسي على مستويات فردية وجماعية (حملات الحج). ومع ذلك، يضمن SEM رفع هذه العناصر إلى المستوى الثقافي والدولي، مقدماً الدعم على مستوى تنظيم الحج والسياسات، مع التأكيد على حساسية الاختلافات الثقافية والتأثير البيئي المجتمعي. يتيح دمج HBM و SEM في برامج التعليم الصحي للحج تدخلاً شاملاً يتناول كل من العوامل المعرفية الفردية والتأثيرات الاجتماعية والبيئية الأوسع نطاقاً التي تؤثر على سلوكيات الصحة. يضمن هذا الإطار المنهجي التكيف الثقافي والفعالية لتحقيق أربعة أهداف رئيسية: (1) تعزيز التعديلات الإيجابية للسلوك الصحي للأفراد والمجموعات من خلال التعامل مع المخاطر الصحية ذات العلاقة بالحج، (2) تعزيز فهم الحجاج الدوليين للنظام الصحي المحلي واستخدامه بفعالية، وبالتالي (3) تحسين النتائج الصحية للأفراد والمجموعات، و(4) تخفيف الضغط على النظام الصحي خلال فترة الحج.

الكلمات الدالة: السلوك الصحي، برامج التوعية والتثقيف الصحي، الحج، HBM، SEM

## Abstract

The significance of health promotion and education programs for prospective pilgrims cannot be overstated, as they make a substantial impact on the welfare and safety of individuals undertaking religious pilgrimages, especially the Hajj in Makkah. There is a dearth of comprehensive research on health services orientation programs for travelers. The purpose of this paper is to outline the components of a proposed health education program that will be provided to pilgrims (Hajj and Umrah visitors) prior to their departure to Saudi Arabia. Utilizing the foundational principles of the Health Belief Model (HBM) and the Social Ecological Model (SEM), this paper delineates the essential components and procedural steps of a theoretical framework.

This framework is specifically crafted for the development of health awareness programs targeted at international pilgrims, accommodating the vast array of cultural backgrounds they represent. Similar to SEM, the framework includes five main levels: Individual, Interpersonal Level, Organizational, Community, and policy Level. Among the most important elements included in these guidance levels are awareness lectures on health risks during Hajj, education on the advantages of preventive measures, the participation of authentic campaign leaders and preachers in disseminating health information among their campaign members, and practical training on infection control measures and basic aid. These elements primarily occur on individual and group (e.g., Hajj campaigns) levels. However, SEM ensures that these elements are elevated to the cultural and international level, offering support at the Hajj organization and policy levels, emphasizing both cultural sensitivity and ecological impact. The integration of HBM and SEM in health education programs for the Hajj enables a comprehensive intervention that addresses both individual cognitive factors and broader social and environmental influences impacting health behaviors. The outlined framework guarantees cultural sensitivity and efficacy to achieve four goals: (1) enhance health behavioral change, (2) improve healthcare utilization, (3) boost health outcomes, and (4) alleviate strain on healthcare during Hajj.

**Keywords:** Health behavioral change, health promotion and education, Hajj, HBM, SEM.

## 1. Introduction

The pilgrimage to Makkah for Hajj and Umrah is a deeply spiritual experience for Muslims worldwide, but it also brings significant health challenges. Pilgrims encounter a range of pre-existing health conditions, particularly older individuals who require specialized healthcare due to vulnerabilities associated with aging (e.g., comorbidities) (Memish et al., 2019; Al Ruwaithi, 2021). Participation in the Hajj exposes individuals to numerous factors, each contributing to unique health risks, including seasonal variations, extreme temperatures, extensive travel, close interaction with diverse populations, and dietary changes. Furthermore, the disorientation associated with the utilization of local healthcare systems by both international visitors and individuals from various backgrounds in Saudi Arabia has a profound impact on healthcare resources and operational efficiency (Al Ruwaithi, 2021). As an illustration, a significant percentage of patients reported to the emergency medical services (EMS) system during the Hajj are classified as non-emergency cases (Al Ruwaithi, 2021).

A correlation has been found between the exposure of pilgrims to health education programs and their engagement in positive health behavior, specifically in terms of adhering to preventive measures (e.g., wearing face-mask) (Tobaigy et al., 2021). The components of such programs have not been clearly illustrated to assess whether they encompass pilgrims' orientation towards utilizing the local health system during Hajj or solely prioritize preventive public health



measures. We are not aware of any formal educational health programs delivered to pilgrims prior to their travel for the purpose of orienting them to the local health system in Makkah.

Health behavioral change theories combined provide a comprehensive framework for designing effective health communication strategies and interventions, leading to better health outcomes for travelers (Chuang et al., 2018; Rejeski & Fanning, 2019; Degarege et al., 2019; de Leeuw et al., 2015). For example, the Social Cognitive Theory and Theory of Planned Behavior can further influence travel health behaviors through social modeling and by addressing travelers' attitudes, perceived norms, and control over healthy actions (Rejeski & Fanning, 2019). Health behavioral change theories, such as the Health Belief Model (HBM) and Stages of Change Model, can significantly enhance travelers' health by promoting preventive behaviors like vaccinations and safe food choices, tailored to their readiness and belief in the severity and susceptibility to travel-related health risks. The current paper aims to outline a framework to design health education programs to be provided to pilgrims (Hajj and Umrah visitors) prior to their departure to Saudi Arabia.

## 2. Methodology (Materials and methods)

This paper aims to outline a framework guide including the components/elements of a successful health promotion and education programs to pilgrims prior to their departure to Saudi Arabia. Two theory-based health behavioral models were selected to enrich such a framework: HBM and the Social Ecological Model (SEM). Each model presents unique advantages and limitations. As an illustration, HBM predominantly focuses on individual health beliefs and decision-making, but it may fail to consider wider societal factors, exhibit inconsistent effectiveness in predicting behaviors across populations, and frequently underestimate the impact of habitual actions. On the other hand, ecological perspectives on health behavior change emphasize a multi-level approach, recognizing that health behaviors are influenced by various factors at individual, interpersonal, organizational, community, and policy levels. (Sallis et al., 2008).

The interplay of these factors at various levels underline the necessity of interventions that address multiple levels for optimal effectiveness. (Sallis et al., 2008). Nonetheless, SEM encounters complexity in implementation and evaluation, demanding significant resources and coordination for interventions, while also presenting challenges in accurately assessing the effectiveness of these interventions across multiple levels. Hence, the utilization of both models to frame (analyze and identify) the components of a successful program for pilgrims offers a comprehensive method to fulfill this objective concerning the individual determinants and challenging conditions of the Hajj. A thorough assessment of pilgrims' health needs, behaviors, and Hajj health environment based on literature was conducted to recognize a tailored-to-pilgrims-and-Hajj educational health program.

In the context of this paper, health promotion is defined as a comprehensive concept that encompasses various strategies with the objective of promoting overall health and well-being and focuses on enabling individuals and communities to increase control over and improve their health (Kumar & Preetha, 2012). The health promotion is multidisciplinary approach, involving policies, changes in the environment, public health campaigns, and community development to improve health outcomes on a wider scale (Kumar & Preetha, 2012; Whitehead, 2004). Conversely, health education concentrates on a more particular dimension of health promotion, involving activities aimed at improving individuals' understanding and abilities, empowering them to make informed decisions about their health (Whitehead, 2004).

### 3. Findings: The Framework

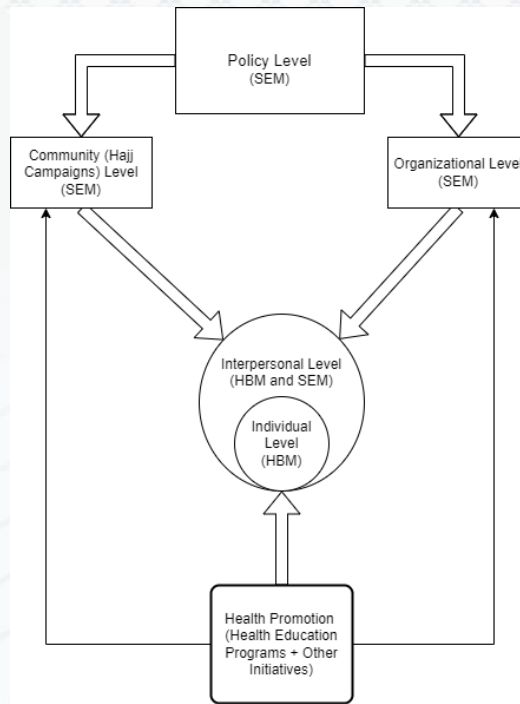
The primary objectives of health promotion and education programs during the Hajj are twofold: (1) mitigating health risks associated with Hajj settings and activities, and (2) enhancing the overall health status of pilgrims and participants in the Hajj. Drawing upon pertinent literature, we have developed an all-encompassing framework for a health promotion program during Hajj. This framework utilizes the HBM and SEM, seamlessly integrating fundamental components from both models. The proposed framework for health promotion during Hajj encompasses various levels, incorporating elements from the HBM and SEM. The primary goal of the framework is to facilitate the design of health promotion and education programs specifically for pilgrims. Figure 1 demonstrates the framework levels that should be taken into consideration when designing these programs, with their primary linkage to either of the included health behavioral change model theories.

At the Individual Level, the HBM framework evaluates pilgrims' awareness of health risks during Hajj, specifically focusing on their perceived susceptibility and severity of diseases (Champion & Skinner, 2008). Additionally, it considers the perceived benefits and barriers, emphasizing the advantages of preventive measures like vaccination and hygiene, while acknowledging potential obstacles, such as cost and inconvenience. Cues to action are deployed via awareness campaigns employing diverse mediums, such as media outlets, Hajj campaign leaders, and clerics, in order to induce pilgrims to undertake precautionary measures. Furthermore, a strong emphasis is placed on self-efficacy, which empowers pilgrims by instilling them with the necessary confidence and skills to adopt and sustain health-promoting behaviors. Each of those components plays a pivotal role in driving change at the individual level.

Moving to the Interpersonal Level (HBM and SEM), this framework leverages social networks, community, and family structures to disseminate health information, encouraging collective adherence to preventive measures. Emphasizing collaboration with religious leaders (Hajj campaign leaders and clerics) enhances the credibility of health recommendations by incorporating health messages into sermons. The proposed framework suggests the establishment of health support groups for pilgrims within the Hajj communities (Hajj campaigns) to exchange experiences, offer motivation, and reinforce behaviors that promote good health.

At the Organizational Level, the framework guarantees the provision of accessible and affordable healthcare services for pilgrims. Pre-Hajj orientation includes the inclusion of educational programs, which cover hygiene practices, vaccination requirements, disease prevention, and, more importantly, the orientation on health system utilization during the Hajj. Communication channels, including hotlines and mobile apps, should be established within those health promotion programs to provide real-time health updates and emergency information to pilgrims.

The framework in the context of Community Level (SEM) highlights the importance of engaging with the local communities surrounding Hajj sites, in order to cultivate a supportive environment for the health of pilgrims. Environmental factors are addressed in the model to ensure clean and sanitary conditions in pilgrimage areas, mitigating factors contributing to health risks. Additionally, the framework places significant importance on the Policy Level (SEM), wherein regulatory measures such as vaccination requirements and hygiene standards for pilgrims are implemented and enforced. Emphasizing collaboration with both local and international health authorities is crucial in aligning the health promotion program with broader public health initiatives.



**Figure 1.** The framework of designing a promotional health education based on HBM and SEM.

The Individual Level focuses on the Health Belief Model (HBM) components of perceived susceptibility, severity, benefits, barriers, cues to action, and self-efficacy. The Interpersonal Level combines HBM and Social Ecological Model (SEM) theories, focusing on social networks, religious leaders, health support groups, and public health professionals. The Organizational Level encompasses health services, educational programs, and communication channels. The Community Level efforts include Hajj community engagement in designing the health educational programs and addressing environmental factors. At the Policy Level, there is a focus on both regulatory measures and collaboration with authorities (e.g., Ministry of Health).

In the context of this Framework, the health education, a vital component of health promotion cause, focuses on individual behavior change through knowledge and skill development. The health promotion here adopts a broader scope, targeting social and environmental determinants to improve health outcomes. The health promotion approach addresses the broader determinants of health and focuses on a wide range of social and environmental interventions. It is multidisciplinary, involving policies, changes in the environment, public health campaigns, and community development to improve health outcomes on a wider scale.

Public health professionals working on designing and implementing health promotion and education programs can gain a comprehensive perspective on the potential health impacts on pilgrims and identify crucial areas of influence through the framework levels. As the framework primarily focuses on a broad scale, it lacks clear instructions for the finer aspects. To address this, we have outlined the subsequent steps as a practical manual for implementing the framework to develop a health education program for Hajj and Umrah pilgrims. Such programs will be built upon the principles of the HBM and SEM and follow these practical steps, tailored to the Hajj context:

1. **Assessment and Analysis:** Conduct an initial assessment to identify the specific health needs and challenges faced by pilgrims. This includes analyzing past health issues reported during Hajj and gathering data from previous pilgrims and healthcare providers.

2. **Curriculum Development:** Design a comprehensive health education curriculum that addresses identified needs. This curriculum will incorporate information about health risks, preventive measures, basic infection control, and first aid. The content will be culturally sensitive and translated into multiple languages to cater to a diverse group of pilgrims.
3. **Training of Health Educators:** Select and train health educators, including Hajj campaign leaders and clerics, to ensure effective dissemination of health information. These educators will be equipped with the necessary skills to communicate health messages clearly and culturally appropriately.
4. **Implementation of Education Sessions:** Conduct educational sessions using a variety of formats, including face-to-face meetings, digital platforms, and printed materials, to ensure wide reach and accessibility for all pilgrims.
5. **Evaluation and Feedback:** Implement a system for evaluating the effectiveness of the education program. This includes collecting feedback from pilgrims and educators, and assessing changes in knowledge, attitudes, and practices regarding health during Hajj.
6. **Continuous Improvement:** Use feedback and evaluation results to continuously update and improve the health education program, ensuring it remains relevant and effective for future pilgrimages.

Ultimately, this framework integrates the HBM's emphasis on individual beliefs and perceptions with the SEM's multi-level approach, presenting a holistic strategy for promoting health during Hajj. Its goal is to consider a range of factors that impact health behaviors and establish an environment that promotes the well-being of pilgrims.

#### 4. Discussion:

The proposed framework (Figure 1) illustrates the interconnectedness of various levels of influence on health behavior as per the HBM and the SEM. At its center, individual health behaviors are influenced by personal beliefs about health threats and outcomes (as per HBM). These are directly impacted by interpersonal relationships and community support systems (as per SEM). The broader community, organizational structures, and policy levels exert a secondary influence, shaping the environment in which individuals and interpersonal networks operate. This holistic framework highlights the dynamic and multilayered nature of health promotion, emphasizing the importance of interventions at multiple levels to effect change in health behaviors.

The proposed framework aims to develop and validate a culturally sensitive health education strategy to promote health and well-being among pilgrims. Such a program could include awareness lectures, preventive health measures education, and practical training in infection control. The framework's application aims to align health behaviors with the Hajj environment and the Saudi Arabian healthcare system, enhancing positive change of behavioral health among pilgrims and Hajj campaigns and reducing medical service misuse due to dealing with unfamiliar healthcare systems.

Tobaigy et al (2021) conducted a study involving 1012 questionnaires completed by pilgrims from 41 nationalities, revealing that the majority of participants, totaling 799 individuals (78.9%), had received some form of health education regarding preventative measures, particularly in relation to hygiene aspects. As per the survey findings, the majority of participants (44.4%) received their education primarily in their respective home countries, accounting for a total of 450 individuals. Despite the limited information on the structure and formality of these programs, a study conducted by Tobaigy et al. (2021) discovered a positive correlation between receiving health education and engaging in preventative measures, such as wearing face masks in crowded areas ( $p = 0.04$ ), as well as other health practice scores ( $p = 0.02$ ).

However, it is unclear whether such health education incorporates an orientation program that educates pilgrims on utilizing the local health system in Makkah and Medinah.

Relevant literature highlights the essential role of incorporating comprehensive, theory-driven strategies in fields such as health promotion, behavioral change, environmental education, and organizational management (Rejeski and Fanning, 2019; Batras et al., 2016; Trickett et al., 2011; Sung and Kim, 2021; Michie et al., 2011). Diverse approaches require a dedication to collaborative methodologies, cultural sensitivity, and the pursuit of sustainable practices, while highlighting the interdependence of theory, community engagement, and individual behavior in achieving effective and lasting outcomes (degarege et al., 2019; Rejeski and Fanning, 2019; Trickett et al., 2011; Michie et al., 2011). This paper highlights the amalgamation of the HBM and SEM within a cohesive framework provides a comprehensive and straightforward approach. With careful design, this innovative framework aims to be both inclusive and manageable, thereby ensuring the effectiveness of health education among pilgrims.

The HBM focuses on intrapersonal components, emphasizing an individual's perceptions and beliefs about health conditions. This model is particularly effective in understanding and addressing personal attitudes towards health risks and benefits of preventive behaviors, making it a crucial component of the framework. The model posits that health-related action is likely when individuals perceive a high severity and susceptibility to a health condition, perceive benefits in taking action, and see fewer barriers to taking such action (Abraham & Sheeran, 2015). The HBM is positioned as a pivotal tool in understanding and motivating health-related behavior changes, especially in the context of preventive healthcare (Irwin, 1974; Champion & Skinner, 2008).

The SEM extends the focus beyond the individual to include external and ecological factors. It acknowledges that individual behavior is influenced not only by personal beliefs and attitudes, but also by the social and physical surroundings (Glanz et al., 2008). This involves bonds with peers and family members, community networks, organizational systems, and even broader societal elements (Davis et al., 2015). Sallis et al. (2008) highlights that Ecological models are most powerful when tailored to specific behaviors, acknowledging that each health behavior may require unique environmental and policy considerations (Sallis et al., 2008). By leveraging these qualities, the present framework effectively implements health education programs tailored to specific settings and health risks, while accounting for variations in individual health profiles. That is, the framework considers the complexity of behavioral change, influenced by various factors surrounding pilgrims, by incorporating HBM and SEM.

The purpose of merging these two models is to adopt a holistic approach that acknowledges the impact of personal beliefs alongside the societal and environmental factors that shape health behaviors. This duality ensures that health promotion and education programs for Hajj pilgrims are not only based on individual awareness and motivation but also consider the social and cultural context of the pilgrims, enhancing the effectiveness and relevance of these programs.

## 5. Conclusions

The Hajj environment presents pilgrims with various health risks and disorientation of utilizing local healthcare systems that demand extensive collaborative endeavors. Notwithstanding the foundations of health promotion and education programs, there is a distinct absence of comprehensive research on health services orientation programs for travelers. The current paper presents a comprehensive framework that provides guidance for the design and implementation of health promotion and education programs tailored to pilgrims traveling to Makkah for Hajj and Umrah. This framework is informed by two health behavioral theoretical models. The proposed framework effectively combines the HBM and

SEM, with a strong emphasis on cultural sensitivity. By doing so, it comprehensively addresses both individual cognitive factors and wider social and environmental influences on health behaviors.

The framework encompasses various levels - individual, interpersonal, organizational, community, and policy - to promote positive health behavior changes, improve healthcare utilization, boost health outcomes, and alleviate healthcare system strain during the Hajj. The framework supports a holistic strategy for international pilgrims, aligning health behaviors with the Saudi Arabian healthcare system and improving the well-being of the pilgrimage communities. The current framework is theoretically poised, yet it requires empirical validation for gauging its effectiveness in the unique context of the Hajj.

## 6. Recommendations

It is advised to implement health promotion and education initiatives anchored in theoretical models of health behavioral change. Formulating these programs, tailored for pilgrims traveling to Makkah, is essential. It empowers them and their pilgrimage companies by reducing health risk exposure and enhancing utilization of the local healthcare system. This theoretical framework, culturally sensitive and effective, aims to achieve four key objectives: (1) fostering health behavioral change, (2) optimizing healthcare utilization, (3) improving health outcomes, and (4) reducing the burden on healthcare services during Hajj. However, the framework is poised for trial among pilgrims, and cautions that its outcomes should be applied carefully.

## References

- Abraham, C., & Sheeran, P. (2001). The health belief model. In *Cambridge Handbook of Psychology, Health and Medicine* (pp. 97–102). Cambridge University Press. <https://doi.org/10.1017/CBO9780511543579.022>
- Ahmed, Q. A., Arabi, Y. M., & Memish, Z. A. (2006). Health risks at the Hajj. *The Lancet (British Edition)*, 367(9515), 1008–1015. [https://doi.org/10.1016/S0140-6736\(06\)68429-8](https://doi.org/10.1016/S0140-6736(06)68429-8)
- Al Ruwaithi, A. A. (2021). *The Emergency Medical Services Delivery in Mass Gathering Events: A Case Study of the Hajj*. ProQuest Dissertations Publishing.
- Batras, D., Duff, C., & Smith, B. J. (2016). Organizational change theory: implications for health promotion practice. *Health Promotion International*, 31(1), 231–241. <https://doi.org/10.1093/heapro/dau098>
- Champion, V. L. & Skinner, C. S. (2008). The Health Belief Model. In Glanz, K., Rimer, B. K., & Viswanath, K. (Eds), *Health Behavior and Health Education: Theory, research, and practice*, 4(45-65).
- Chuang, L.-M., Chen, P.-C., & Chen, Y.-Y. (2018). The Determinant Factors of Travelers' Choices for Pro-Environment Behavioral Intention-Integration Theory of Planned Behavior, Unified Theory of Acceptance, and Use of Technology 2 and Sustainability Values. *Sustainability (Basel, Switzerland)*, 10(6), 1869-. <https://doi.org/10.3390/su10061869>
- Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: a scoping review. *Health Psychology Review*, 9(3), 323–344. <https://doi.org/10.1080/17437199.2014.941722>
- De Leeuw, A., Valois, P., Ajzen, I., & Schmidt, P. (2015). Using the theory of planned behavior to identify key beliefs underlying pro-environmental behavior in high-school students: Implications for educational interventions. *Journal of environmental psychology*, 42, 128-138.
- Degarege, A., Krupp, K., Fennie, K., Srinivas, V., Li, T., Stephens, D. P., & Madhivanan, P. (2019). An integrative behavior theory derived model to assess factors affecting HPV vaccine acceptance using structural equation modeling. *Vaccine*, 37(7), 945–955. <https://doi.org/10.1016/j.vaccine.2019.01.012>

- Glanz, K., Rimer, B. K., & Viswanath, K. (2008). *Health Behavior and Health Education: Theory, research, and practice in health behavior and health education* (Fourth edition). Jossey-Bass.
- Kumar, S., & Preetha, G. (2012). Health promotion: an effective tool for global health. *Indian Journal of Community Medicine*, 37(1), 5–12. <https://doi.org/10.4103/0970-0218.94009>
- Memish, Z. A., Zumla, A., Alhakeem, R. F., Assiri, A., Turkestani, A., Al Harby, K. D., Alyemni, M., Dhafar, K., Gautret, P., Barbeschi, M., McCloskey, B., Heymann, D., Al Rabeeah, A. A., & Al-Tawfiq, J. A. (2014). Hajj: infectious disease surveillance and control. *The Lancet (British Edition)*, 383(9934), 2073–2082. [https://doi.org/10.1016/S0140-6736\(14\)60381-0](https://doi.org/10.1016/S0140-6736(14)60381-0)
- Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation Science : IS*, 6(1), 42–42. <https://doi.org/10.1186/1748-5908-6-42>
- Rejeski, W. J., & Fanning, J. (2019). Models and theories of health behavior and clinical interventions in aging: a contemporary, integrative approach. *Clinical Interventions in Aging*, 14, 1007–1019. <https://doi.org/10.2147/CIAS.206974>
- Rosenstock, I. M. (1974). The Health Belief Model and Preventive Health Behavior. *Health Education Monographs*, 2(4), 354–386. <https://doi.org/10.1177/109019817400200405>
- Sallis, J. F., Owen, N., & Fisher, E. (2008). Ecological models of health behavior. In Glanz, K., Rimer, B. K., & Viswanath, K. (Eds), *Health Behavior and Health Education: Theory, research, and practice*, 4(465-85).
- Sung, W., & Kim, C. (2021). A Study on the Effect of Change Management on Organizational Innovation: Focusing on the Mediating Effect of Members' Innovative Behavior. *Sustainability (Basel, Switzerland)*, 13(4), 2079-. <https://doi.org/10.3390/su13042079>
- Tobaigy, M., Alhasan, A. H., Shams, M. M., Amer, S. A., MacLure, K., Alcattan, M. F., & Almudarra, S. S. (2020). Assessment of Preventative Measures Practice among Umrah Pilgrims in Saudi Arabia, 1440H-2019. *International Journal of Environmental Research and Public Health*, 18(1), 257-. <https://doi.org/10.3390/ijerph18010257>
- Trickett, E. J., Beehler, S., Trimble, J. E., Deutsch, C., Green, L. W., Hawe, P., Mcleroy, K., Lin Miller, R., Rapkin, B. D., Schensul, J. J., & Schulz, A. J. (2011). Advancing the Science of Community-Level Interventions. *American Journal of Public Health (1971)*, 101(8), 1410–1419. <https://doi.org/10.2105/AJPH.2010.300113>
- Whitehead, D. (2004). Health promotion and health education: advancing the concepts. *Journal of Advanced Nursing*, 47(3), 311–320. <https://doi.org/10.1111/j.1365-2648.2004.03095.x>



## Bibliometric Analysis of Health-Related Research on Hajj and Umrah in Saudi Arabia (1900-2023)

Hammad Alhasan

Medical rehabilitation sciences Department, Umm Al-Qura University.

\*Corresponding author: E-mail (hshasan@uqu.edu.sa)

### التحليل الببليومتري للأبحاث الصحية المتعلقة بالحج والعمرة في المملكة العربية السعودية (1900-2023)

حمّاد سجّاد الحسن

قسم علوم التأهيل الطبي، جامعة أم القرى

#### المخلص

تم استخدام الكلمات الرئيسية المتعلقة بالحج والعمرة في قاعدة بيانات ويب أوف ساينس واسترجاع جميع المقالات المنشورة من عام 1900 إلى عام 2023. اقتصرت المقالات المضمنة على تلك الموجودة في المجال الصحي. تم تحديد ما مجموعه 491 دراسة. (1) تضمنت الدراسات المستردة 3,730 مؤلفًا، بمتوسط 7.5 مؤلف لكل دراسة، وإجمالي 9,880 استشهادًا، بمتوسط 20.1 استشهاد لكل دراسة. (2) تصدرت جامعة الفيصل عدد المنشورات بـ 76 مساهمة، في حين حصل الباحث زياد مميش على المركز الأول بمجموع 135 منشورًا. (3) المجالات المستهدفة للنشر في هذا المجال هي: طب السفر والأمراض المعدية (العدد = 55)، تليها المجلة الطبية السعودية (العدد = 34). (4) كشف إجراء تحليل متزامن للكلمات الرئيسية للمؤلف عن المجالات الرئيسية ذات الاهتمام البحثي وهي: الأمراض المعدية واللقاحات وكوفيد-19 والصحة العامة. (5) تركزت موضوعات البحث الرئيسية حول وبائيات الأمراض المعدية، ومسبباتها، وانتشارها، والوقاية منها. (6) ونتيجة لذلك، ظهرت ثلاثة تخصصات شاملة، تشكل مشهد أبحاث الحج والعمرة في المملكة العربية السعودية: الأمراض المعدية، وطب السفر، والصحة العامة. لوحظ وجود تعاون محدود بين الباحثين السعوديين وأولئك الذين ينتمون إلى البلدان المنخفضة الدخل. بالإضافة إلى ذلك، تم تحديد نقص في الدراسات الشاملة التي تعالج مشاكل العضلات والعظام التي تواجه الحجاج والمعتمرين. في المجمل توفر هذه النتائج رؤى قيمة حول الوضع الحالي للبحث وتوفر فهمًا شاملاً للباحثين، وتوجيه اتجاهات البحث المستقبلية المحتملة.

#### Abstract

This study aims to offer a succinct analysis of health-related publications on Hajj and Umrah in Saudi Arabia using bibliometric analysis tools. The keywords "Hajj" "Umrah" or "Hajj and umrah" were utilized in the Web of Science database. All peer-reviewed published articles from 1900 to 2023 were retrieved. A total of 491 studies were identified. (1) The retrieved documents had 3,730 authors averaging 7.5 authors per document and a total of 9,880 citations averaging approximately 20.1 citations per document. (2) Alfaisal University led in publication count with 76 contributions, while Ziad A. Memish secured the top position with a total of 135 publications. (3) The primary journals for publications in the field were: Travel Medicine and Infectious Disease (n=55), followed by the Saudi Medical Journal (n=34). (4) Conducting a co-occurrence analysis of author keywords revealed key areas of research interest in infectious



diseases, vaccines, COVID-19, and public health. (5) The major research themes in the field were centered around infectious disease epidemiology, etiology, prevalence, and prevention. (6) Consequently, three overarching disciplines emerged shaping the landscape of Hajj and Umrah research in Saudi Arabia: infectious diseases, travel medicine, and public health. Limited collaboration was observed between Saudi scholars and those from low-income countries. Additionally, a shortage of comprehensive studies addressing musculoskeletal issues faced by Hajj and Umrah pilgrims was identified.

**Keywords:** Hajj, Umrah, Bibliometrics, Saudi Arabia, Health.

## 1. Introduction

Muslims around the world travel to Saudi Arabia (Mecca/Makkah) for pilgrimage activities. Hajj and Umrah hold significant importance in Islam rooted deeply in religious and cultural significance, both being crucial pilgrimage activities. Muslims are urged to perform Hajj and Umrah as it is considered an essential religious activity. Umrah which is a minor pilgrim can be performed any time during the year, while Hajj is only performed in a specific period. Hajj and Umrah which is a form of religious travel has grown in popularity and attracted a sizable market share in all over the world especially for Saudi Arabia and Muslim countries. (Al-Tawfiq et al., 2017). According to The Saudi Ministry of Hajj and Umrah approximately 25 million national and international Muslims performed Hajj and Umrah in 2022 (The Saudi Ministry of Hajj and Umrah, 2022). The majority of pilgrims were international pilgrims with 781,409 pilgrims performing Hajj and 8,372,429 pilgrims performing Umrah (General Authority for Statistics, 2022).

Hajj and Umrah fall within the category of mass gathering which is defined as an "event or situation in which a large number of people come together in a specific location for a common purpose, such as a festival, sporting event, concert, religious pilgrimage, or other public gathering" (Lombardo et al, 2008). Therefore, Hajj and Umrah falls into the category of religious pilgrimage. The nature of Hajj and Umrah place a significant stress on pilgrims which can put their health at risk. Several common health concerns are encountered by pilgrims during Hajj and Umrah. To provide an overview of these issues, the following conditions are frequently reported: First, respiratory infections such as Influenza are the most prevalent health problems observed during Hajj and Umrah. This can be attributed to the close proximity of large crowds and the dusty environmental conditions (Benkouiten et al, 2019). Second, heat-related illnesses, particularly heatstroke pose a significant risk especially during the sweltering and humid summer months in Mecca (Yezli et al, 2023). Third, cardiovascular diseases including heart attacks are a leading cause of mortality among pilgrims and often result from the physical demands of Hajj and Umrah rituals (Altebainawi et al, 2023). Other health issues encompass gastrointestinal illnesses, musculoskeletal injuries, and skin infections (Alshehri et al, 2021; Hoang et al, 2021).

Many pilgrims fall into categories such as older adults, individuals with obesity, or those with low cardiovascular fitness. These factors, along with the attitudes and behaviors of pilgrims, should be taken into account to minimize the occurrence of health-related problems during Hajj and Umrah (Yezli, 2023). Given the physically demanding nature of the Hajj pilgrimage, it is crucial to be aware of health risks and take proactive measures to address them. Quantitatively analyzing the growth and development of publications within a specific field is achieved through bibliometric analysis, which utilizes mathematical and statistical tools (Moed, 2006). When applied to health-related literature such analysis can serve as an indicator of a nation's preparedness to address public health concerns and raise awareness about the health risks associated with Hajj and Umrah. Furthermore, it equips policymakers with the necessary insights for more effective health planning and management of these mass gatherings. Additionally, it enables researchers to identify gaps in the existing body of knowledge (Sweileh, 2022). Hajj and Umrah hold significant importance in Saudi Arabia given the

substantial responsibility for planning and ensuring the safety of pilgrims during the pilgrimage seasons. Consequently, it is imperative to assess the current state of health-related research in the context of Hajj and Umrah in Saudi Arabia. Surprisingly, a comprehensive bibliometric overview of the topics covered in research related to Hajj and Umrah is notably absent in the literature. As far as the author is aware, no bibliometric study has been conducted to evaluate health-related literature on Hajj and Umrah within Saudi Arabia. Consequently, the objective of this study is to provide readers, academics, and policymakers with a concise analysis of health-related publications pertaining to Hajj and Umrah in Saudi Arabia. The study's aim is to identify and summarize the trends in previous research concerning Hajj and Umrah and to offer a concise overview for researchers and practitioners with an interest in this domain.

## 2. Methodology (Materials and methods)

This is a cross-sectional study focused on the analysis of documents published in peer-reviewed journals related to Hajj and Umrah.

### Database and search strategy

The relevant publications were sourced from the Web of Science database. The selection of Web of Science was deliberate as it is an interdisciplinary database that includes top journals across various subject areas. This choice maximizes the probability of accessing the most relevant publications (AlRyalat et al, 2019). Moreover, Web of Science provides a range of analytical features that facilitate the extraction of data for further analysis.

In this particular study, the search was constrained to articles published within health disciplines. The selection of keywords was informed by prior research in the field, (Memish et al, 2019). The search was conducted from the database's inception to November 1, 2023. The search strategy incorporated the following keywords: Hajj OR umrah OR "hajj and umrah". All publication categories, including journal articles and conference papers were encompassed in the analysis. However, book chapters and books were excluded from the selection. The inclusion criteria for publications specified that they should be authored by scientists working in or affiliated with institutions in the Kingdom of Saudi Arabia (KSA) encompassing both Saudi nationals and expatriates. Figure 1 illustrates the analytical framework employed in the present study.

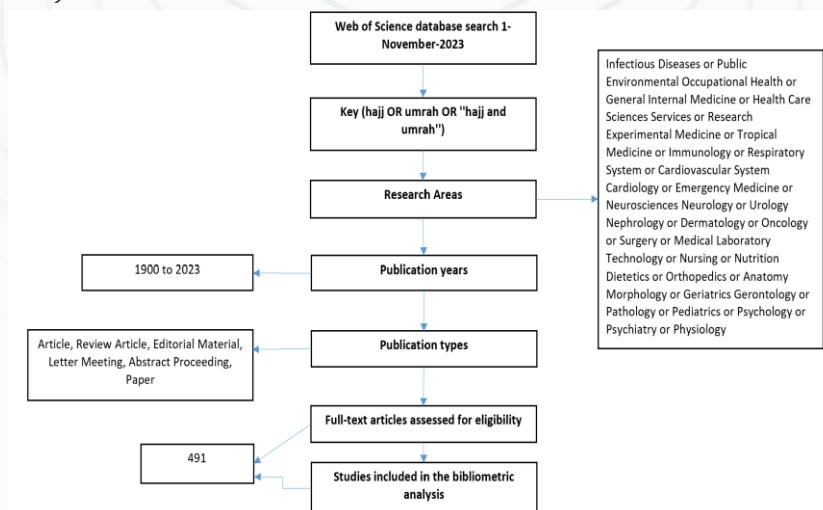


Figure 2 Analytical framework of the study.

### Data export and analysis

The search strategy was executed, and the collected data were exported to Microsoft Excel in both "csv" and "text" file formats. The exported data included various details such as the title and abstract of each document, the names of the author(s), their respective countries and institutional affiliations, author-assigned keywords, the annual publication count, citation counts, and the journal names. To facilitate a visual representation of information related to annual growth, productivity, and citation analysis, this data was presented in the form of linear graphs or tables.

Data regarding common author keywords, prevalent terms in titles/abstracts, cross-country collaborations, and author research networks were visualized using the free software tool, VOSviewer. In VOSviewer maps, nodes are differentiated by different colors and sizes. The size of a node is directly related to its frequency of occurrence, while the color of a node signifies its association with nodes of a similar color.

### 3. Results and Discussion

#### Characteristics of the retrieved documents

The search yielded a total of 491 relevant documents related to Hajj and Umrah. These documents encompassed various types, with the majority being original articles. Additional document types are detailed in Table 1. The retrieved documents collectively featured 3,730 author names with an average of 7.5 authors per document. Notably, 66% (326 out of 491) of the retrieved documents were published in open-access journals and all of them were in the English language. The combined citations for the retrieved documents amounted to 9,880 with an average of approximately 20.1 citations per document. Of the 491 retrieved documents, 43.1% (212 out of 491) featured the keyword "Hajj" in their titles. Figure 2 illustrates the growth pattern of publications, which can be categorized into three distinct phases: an initial development phase (up to 2011), a high-spiking phase (2012-2016), and a fluctuation phase (2017-2023).

Table 6 Types of documents retrieved.

Document Types	Record Count	% of 491
Article	317	64.6
Review Article	60	14.1
Editorial Material	54	10.2
Letter	41	7.5
Meeting Abstract	14	2.9
Proceeding Paper	5	1.0

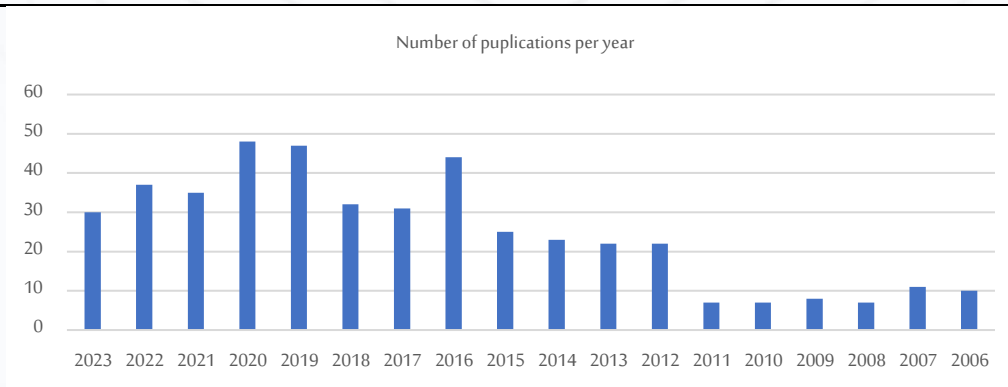


Figure3 The growth of publications and citations related to Hajj and Umrah.

### Major contributors to the field in Saudi Arabia

Table 2 provides an overview of the top ten universities and colleges contributing to this field. Alfaisal University holds the top position with 76 articles, followed by King Saud University.

Table 7 Top 10 Universities' Contributions to the Field of Hajj and Umrah in Saudi Arabia.

Affiliation with Department	Record Count	% of 491
Alfaisal University College of Medicine	76	15.5
King Saud University College of Medicine	55	11.2
The University of Sydney Faculty of Medicine and Health	42	8.6
Emory University Woodruff Health Sciences Center	36	7.3
Emory University Hubert Department of Global Health	34	6.9
The University of Sydney Institute for Infectious Diseases	31	6.3
The University of Sydney School of Medicine	29	5.9
King Abdulaziz University Faculty of Applied Medical Sciences	23	4.7
The University of Sydney Faculty of Science	23	4.7
The University of Sydney School of Life and Environmental Sciences	23	4.7

### Core journals

The retrieved documents were distributed across 165 different peer-reviewed scientific journals and the Travel Medicine and Infectious Disease Journal held the top position with the highest number of publications (51 documents, accounting for 10.3% of the total). Table 3 presents the top ten journals with the most contributions. It is noteworthy that the majority of the journals in this core list were focused on infectious diseases and public health.

Table 3. Core journals in Hajj and Umrah health-related research.

Rank	Journal	Record Count	% of 491
1	Travel Medicine and Infectious Disease	51	10.4
2	Saudi Medical Journal	34	6.9
3	International Journal of Infectious Diseases	24	4.9
4	Journal of Travel Medicine	21	4.3
5	Lancet	16	3.3
6	International Journal of Environmental Research and Public Health	14	2.9
7	Journal of Epidemiology and Global Health	12	2.4
8	Vaccine	12	2.4
9	Pakistan Journal of Medical Sciences	11	2.2
10	Cureus Journal of Medical Science	9	1.8

### Leading authors

In total, the publication of the retrieved documents involved the contributions of 3,730 authors. Notably, Ziad A. Memish from Saudi Arabia ranked at the top with 135 publications representing 27.5% of the total. Table 4 offers a list of the top ten key researchers in the field.

Table 4. Highly influential researchers who publish health-related papers on Hajj and Umrah.

Authors	Country of origin	Record Count	% of 491
Memish Z.A	Saudi Arabia	135	27.5
Yezli S	Saudi Arabia	59	12.0
Al-tawfiq J.A	Saudi Arabia	45	9.2
Rashid H	Australia	44	9.0
Gautret P	France	42	8.6
Booy R	Australia	39	7.9
Alotaibi B	Saudi Arabia	23	4.7
Azhar E.I	Saudi Arabia	21	4.3
Khan A	Saudi Arabia	21	4.3
Parola P	France	21	4.3

### Networks of author collaboration

Figure 3 offers a network visualization map of authors, with a minimum of 15 publications each. This map visually illustrates the collaborative connections among authors, shedding light on various research groups and their associations. The map included a total of 18 authors, with each cluster indicating a unique research group. Notably, three prominent clusters were evident on the map:

1. The yellow and green cluster, which included 8 authors represented Saudi researchers. These clusters exhibited the highest number of collaborative connections with the other two clusters on the map. This indicates a strong level of collaboration and interaction between Saudi researchers and researchers from other regions.
2. The blue cluster represented Australian researchers
3. The green cluster represented French researchers.

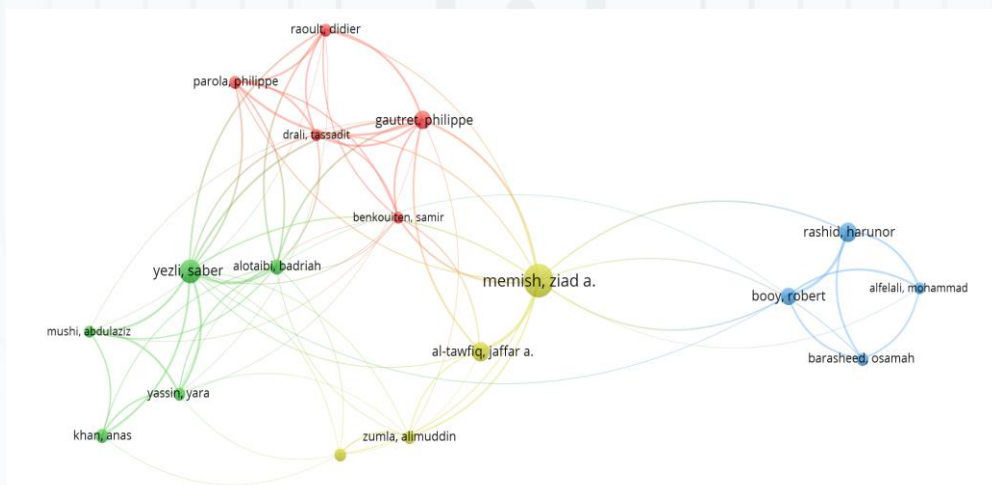


Figure 4 This map depicts collaborative research networks among researchers who have authored a minimum of 15 documents.

### Co-authorship countries (Networks of international research collaboration)

In Figure 4, Saudi Arabia is centrally positioned emphasizing its collaborative relationships with many of the countries depicted on the map. The most robust international research collaboration was observed between Saudi Arabia and the United States (USA).

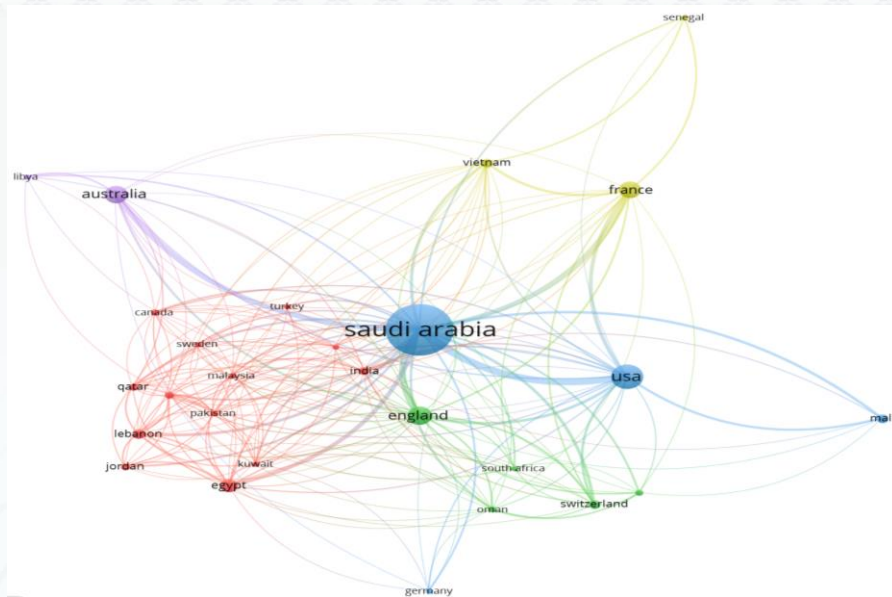


Figure 4. A representation of collaborative research networks between countries that have 5 or more publications. The thickness of the connecting lines between two countries is indicative of the intensity or strength of their research collaboration

#### Co-occurrence analysis of author keywords (important topics)

Figure 5 illustrates a co-occurrence analysis of author keywords with a minimum occurrence of five instances. By using the method of co-occurrence analysis high-frequency keywords have been identified and categorized into four clusters corresponding with the areas of research interest in the field. These areas are as follow: infectious disease, vaccine, covid-19 and public health. Common non-specific keywords such as "Hajj" "Umrah" "Saudi" and "mass gatherings" were excluded to emphasize other more specific keywords relevant to the research areas.

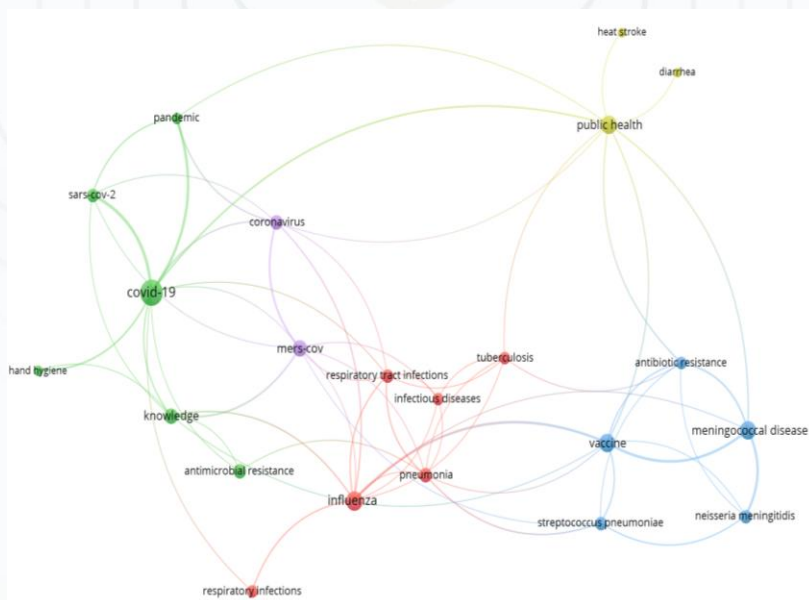


Figure5 A network visualization map of author keywords, with a minimum occurrence of five or more. The map has 22 keywords.

### Most frequent terms in titles/abstracts (major research themes)

Figure 6 is a network visualization map of terms found in titles and abstracts, with a minimum occurrence of five instances. This analysis has revealed three distinct clusters, each representing different research themes:

1. The red cluster corresponds to studies on the epidemiology and etiology of infectious diseases
2. The green cluster is associated with studies on the epidemiology and prevalence of infectious diseases
3. The blue cluster represents studies focusing on the prevention of infectious diseases

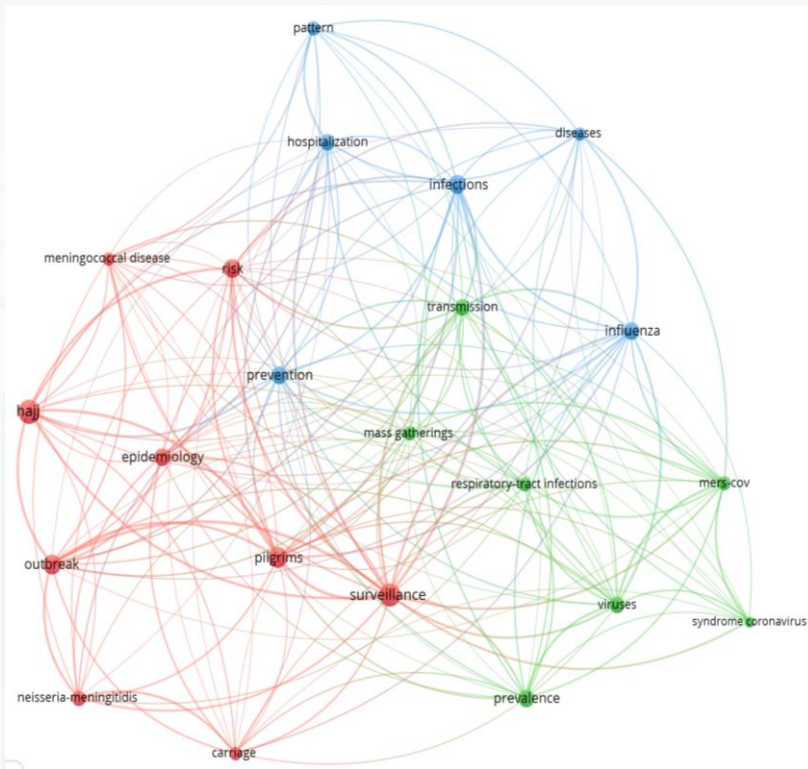


Figure6 network visualization map of terms found in the titles and abstracts.

### Scientific disciplines forming the basis of the field

In Figure 7, a co-citation analysis was carried out involving 99 journals with a minimum citation threshold of 20. The size of the nodes within the figure indicates the journals that were frequently co-cited by journals sharing similar node colors. The subject area(s) represented by the largest node size journals reveal the foundational disciplines of the field. In this particular study, three predominant disciplines were identified: infectious disease, travel medicine, and public health. These disciplines are at the core of the field and play a significant role in the research landscape.

Additionally, Table 5 displays the top five co-cited sources based on both the number of citations and the total link strength, providing valuable insights into the most influential and frequently referenced works in the field.

Citation analysis provides information about the relative importance of publication. Ahmed et al (2006) has the highest number of citations, which is 277, It reflects that the citation document/ paper from this author has the greatest impact in this field of Hajj and Umrah. The top five cited documents based on the citation frequency are illustrated in Table 6.

Table 5. The top five co-citation for the cited sources.

Rank	Cited source	Citation	Total strength link
1	Travel Medicine and Infectious Disease	1290	276
2	International Journal of Infectious Diseases	690	187
3	Lancet	966	165
4	Saudi Medical Journal	597	131
5	Journal of Travel Medicine	528	123

Table 6. The top-cited articles in the field of Hajj and Umrah health.

Journal	Publisher	Most cited article	Author	Times cited
LANCET	ELSEVIER SCIENCE INC	Health risks at the Hajj (2006)	Ahmed et al	277
LANCET	ELSEVIER SCIENCE INC	Hajj: infectious disease surveillance and control (2014)	Memish et al	215
TRAVEL MEDICINE AND INFECTIOUS DISEASE	ELSEVIER SCI LTD	COVID-19 social distancing in the Kingdom of Saudi Arabia: Bold measures in the face of political, economic, social and religious challenges (2020)	Yezli & Khan	203
JOURNAL OF INFECTIOUS DISEASES	OXFORD UNIV PRESS INC	Outbreak of W135 meningococcal disease in 2000: Not emergence of a new W135 strain but clonal expansion within the electrophoretic type-37 complex (2002)	Mayer et al	184
LANCET INFECTIOUS DISEASES	ELSEVIER SCI LTD	Global perspectives for prevention of infectious diseases associated with mass gatherings (2012)	Abubakar et al	181

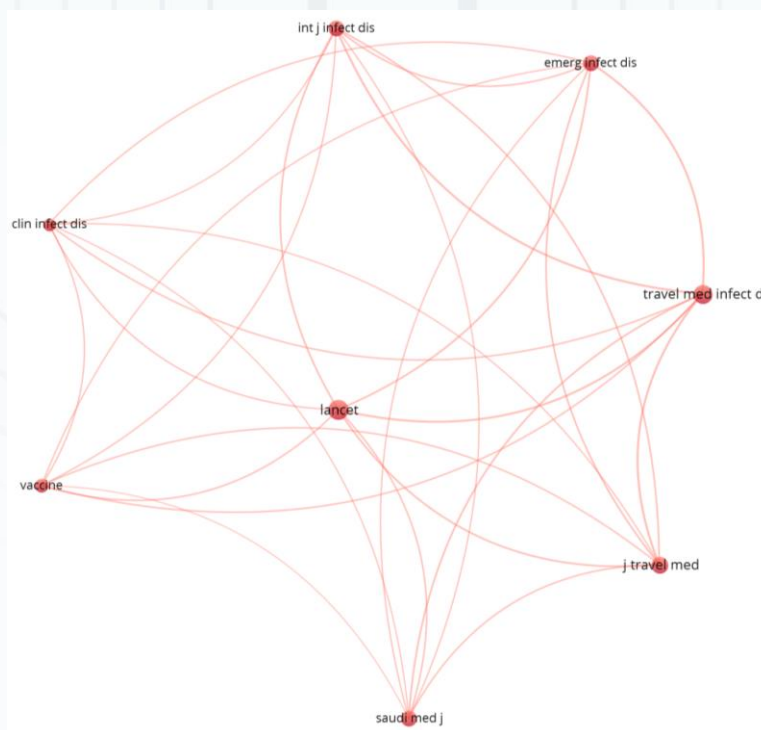


Figure 7 A visual representation of a co-citation analysis among journals.



## Discussion

The present research conducted a bibliometric analysis of health-related publications concerning Hajj and Umrah offering an overview of the field. This research offers a thorough and all-encompassing bibliometric analysis for scholars specializing in the Hajj and Umrah field. In particular, this study assists researchers in visualizing and comprehending maps for co-authorship analysis, co-occurrence analysis, citation analysis, and co-citation analysis.

The following presents a summary of the principal findings from the present study. First, the research field in Saudi Arabia is experiencing growth. Nonetheless, over the past three years there have been fluctuations in the quantity of health-related publications on Hajj and Umrah. Therefore, the quantity of retrieved research articles was comparatively limited. Second, Majority of research focused on Hajj rather than Umrah. Third, Major contributors to the field were Alfaisal University College of Medicine and King Saud University College of Medicine. Finally, Collaboration between Saudi scholar and scholar from low-income countries was limited.

The core journals where the majority of retrieved documents were published include prestigious and high-impact journals, such as *The Lancet*. This underscores the significance and impact of research in the field of Hajj and Umrah. In a recent bibliometric analysis, Saudi scholars and organizations took the lead in terms of most publications related to mass gatherings of Muslims (Sweileh, 2022). This is an anticipated outcome, as Saudi Arabia plays a pivotal role in this field and Hajj and Umrah are organized and overseen by the Saudi government. Surprisingly, in the current study the second and third rankings for contributions to Hajj and Umrah publications are occupied by the United States and England, respectively. This phenomenon can be attributed to the circumstance that numerous Saudi scholars maintain dual institutional affiliations, facilitating broader collaboration and research efforts. Alternatively, it may be explained by some Saudi authors being sponsored by institutions in the USA or UK.

Based on the official data released by General Authority for Statistics (GASTAT) the highest number of pilgrims coming to Saudi were from Indonesia, Pakistan, India, Bangladesh and Nigeria and Malaysia respectively (General Authority for Statistics, 2023). Nevertheless, the findings indicated a lack of collaboration with scholars from these countries. A study found that 35% of Covid-19 cases in Malaysia were linked to the "Sri Petaling" mass gathering attended by thousands of Muslims (Che et al, 2020). Considering that the majority of visitors to Saudi Arabia come from low-income countries, increased collaboration between Saudi scholars and researchers from these nations could make significant contributions to the field. The unique nature of the Hajj pilgrimage, with millions of Muslims converging from various countries, has the potential to facilitate the transmission of infectious diseases (Sweileh, 2022). This rationale justifies the prevalence of studies in the field of infectious diseases.

Co-occurrence analysis of the included studies showed that research topics and themes in the field of Hajj and Umrah is limited to infectious and communicable diseases. Only 22 (4.5%) articles pertained to Health Care Sciences Services, and one article concentrated on enhancing knowledge of healthy behavior among Hajj (Turkestani et al, 2013). A significant number of pilgrims, specifically 80% out of a sample of 1,715 reported experiencing pain after Hajj particularly among females, older adults, and those who are obese. Hajj is physically demanding, often requiring pilgrims to cover long distances on foot which can result in musculoskeletal pain. Unfortunately, a scarcity of comprehensive studies exists that address the musculoskeletal issues pilgrims may encounter during Hajj and Umrah and how these challenges can be effectively managed. It is advisable for future research and surveys to prioritize this issue, and there should be increased availability of educational resources to help pilgrims overcome and manage musculoskeletal problems effectively.

The findings underwent statistical analysis using VOSviewer. Alternative software, such as Hitscite and Gephi, could be considered for future studies. It should be noted that the search was confined to the Web of Science database, which has limitations in capturing documents published in local, unindexed journals. This may lead to an underrepresentation of certain research outputs, particularly those published in regional or non-mainstream outlets. This constraint should be acknowledged when interpreting the findings, recognizing that the entire landscape of research in the field might not be fully encapsulated by the scope of the study, especially if there is a significant body of work in local journals not indexed in the Web of Science database..

#### 4. Conclusions

The field of Hajj and Umrah is rapidly growing in Saudi Arabia. This research offers a thorough and all-encompassing bibliometric analysis for scholars specializing in the Hajj and Umrah field. The findings could offer researchers valuable insights into the present status of research and provide them with a comprehensive understanding of potential future research directions.

#### 5. Recommendations

1. While the field of Hajj and Umrah research in Saudi Arabia is growing, it is crucial to prioritize studies related to Hajj and Umrah for publication in indexed journals.
2. Encourage researchers to diversify their focus beyond infectious and communicable diseases related to Hajj and Umrah.
3. Give priority to studies that specifically address musculoskeletal issues that pilgrims might face during Hajj and Umrah.
4. Emphasize the importance of creating and disseminating educational resources to help pilgrims manage health challenges, particularly musculoskeletal issues.
5. Promote increased collaboration between Saudi scholars and researchers from countries with high numbers of pilgrims, such as Indonesia, Pakistan, India, Bangladesh, Nigeria, and Malaysia.

#### References

- Abubakar, I., Gautret, P., Brunette, G. W., Blumberg, L., Johnson, D., Pomeroy, G., ... & Khan, A. S. (2012). Global perspectives for prevention of infectious diseases associated with mass gatherings. *The Lancet infectious diseases*, 12(1), 66-74. Available at: 10.1016/S1473-3099(11)70246-8.
- Ahmed, Q. A., Arabi, Y. M., & Memish, Z. A. (2006). Health risks at the Hajj. *The Lancet*, 367(9515), 1008-1015. Available at: 10.1016/S0140-6736(06)68429-8.
- AlRyalat, S. A. S., Malkawi, L. W., & Momani, S. M. (2019). Comparing bibliometric analysis using PubMed, Scopus, and Web of Science databases. *JoVE (Journal of Visualized Experiments)*, (152), e58494. Available at: 10.3791/58494.
- Altebainawi, A. F., AlSuhaibani, S. A., & Alshahrani, A. M. (2023). Strategies to curtail the burden of cardiovascular diseases during Hajj activities: A review. *Saudi Journal of Clinical Pharmacy*, 2(3), 75-78. Available at: 10.4103/sjcp.sjcp\_17\_23.
- Alshehri, M. A., Alzaidi, J., Alasmari, S., Alfaqeh, A., Arif, M., Alotaiby, S. F., & Alzahrani, H. (2021). The prevalence and factors associated with musculoskeletal pain among pilgrims during the Hajj. *Journal of Pain Research*, 369-380. Available at: 10.2147/JPR.S293338.
- Benkouiten, S., Al-Tawfiq, J. A., Memish, Z. A., Albarrak, A., & Gautret, P. (2019). Clinical respiratory infections and pneumonia during the Hajj pilgrimage: A systematic review. *Travel medicine and infectious disease*, 28, 15-26. Available at: 10.1016/j.tmaid.2018.12.002.

- Che Mat, N. F., Edinur, H. A., Abdul Razab, M. K. A., & Safuan, S. (2020). A single mass gathering resulted in massive transmission of COVID-19 infections in Malaysia with further international spread. *Journal of Travel Medicine*, 27(3), taaa059. Available at: 10.1093/jtm/taaa059.
- General Authority for Statistics (GASTAT). (2023). Hajj and Umrah Statistics 2022. p. 10. Available at: <https://www.stats.gov.sa/en/28>.
- Hoang, V. T., Dao, T. L., Ly, T. D. A., Sow, D., Belhouchat, K., Larbi Chaht, K., ... & Gautret, P. (2021). Gastrointestinal symptoms and the acquisition of enteric pathogens in Hajj pilgrims: a 3-year prospective cohort study. *European Journal of Clinical Microbiology & Infectious Diseases*, 40, 315-323. Available at: 10.1007/s10096-020-04018-z.
- Lombardo JS, Sniegoski CA, Loschen WA, Westercamp M, Wade M, Dearth S et al. Public health surveillance for mass gatherings. *Johns Hopkins APL Tech Dig*. 2008;27(4):347-355. Available at:
- Mayer, L. W., Reeves, M. W., Al-Hamdan, N., Sacchi, C. T., Taha, M. K., Ajello, G. W., ... & Popovic, T. (2002). Outbreak of W135 meningococcal disease in 2000: not emergence of a new W135 strain but clonal expansion within the electrophoretic type-37 complex. *Journal of Infectious Diseases*, 185(11), 1596-1605. Available at: 10.1086/340414.
- Memish, Z. A., Zumla, A., Alhakeem, R. F., Assiri, A., Turkestani, A., Al Harby, K. D., ... & Al-Tawfiq, J. A. (2014). Hajj: infectious disease surveillance and control. *The Lancet*, 383(9934), 2073-2082. Available at: 10.1016/S0140-6736(14)60381-0
- Memish ZA, Steffen R, White P, Dar O, Azhar EI, Sharma A, et al. Mass gatherings medicine: public health issues arising from mass gathering religious and sporting events. *Lancet*. 2019;393(10185):2073–84. Available at: 10.1016/S0140-6736(19)30501-X
- Moed, H. F. (2006). Citation analysis in research evaluation (Vol. 9). Springer Science & Business Media. Available at: 0264-0473
- Saudi Ministry of Hajj and Umrah. (2023). Umrah Statistics Publication. Available at: <https://www.stats.gov.sa/en/862>
- Sweileh, W. M. (2022). Health-related research publications on religious mass gatherings of Muslims: a bibliometric analysis (1980–2020). *Tropical diseases, travel medicine and vaccines*, 8, 1-10. Available at: <https://tdtmjournal.biomedcentral.com/articles/10.1186/s40794-021-00158-y#citeas>
- Turkestani A, Balahmar M, Ibrahim A, Moqbel E, Memish Z. Using health educators to improve knowledge of healthy behaviour among Hajj 1432. 2011 pilgrims. *East Mediterr Health J*. (2013) 19(Suppl. 2):S9–12. doi: 10.26719/2013.19.Supp2.S9. Available at: [http://applications.emro.who.int/emhj/v19/Supp2/EMHJ\\_2013\\_19\\_Supp2\\_s9\\_s12.pdf?ua=1](http://applications.emro.who.int/emhj/v19/Supp2/EMHJ_2013_19_Supp2_s9_s12.pdf?ua=1)
- WHO Communicable disease alert and response for mass gatherings. Technical workshop. Geneva, Switzerland. April 29–30, 2008. [http://www.who.int/csr/resources/publications/WHO\\_HSE\\_EPR\\_2008\\_8c.pdf](http://www.who.int/csr/resources/publications/WHO_HSE_EPR_2008_8c.pdf) (accessed Aug 26, 2011). Available at: <https://www.who.int/publications/i/item/public-health-for-mass-gatherings-key-considerations>
- Yezli, S., & Khan, A. (2020). COVID-19 social distancing in the Kingdom of Saudi Arabia: Bold measures in the face of political, economic, social and religious challenges. *Travel medicine and infectious disease*, 37, 101692. Available at: 10.1016/j.tmaid.2020.101692
- Yezli, S. (2023). Risk factors for heat-related illnesses during the Hajj mass gathering: an expert review. *Reviews on environmental health*, 38(1), 33-43. Available at: 10.1515/reveh-2021-0097
- Yezli, S., Yassin, Y., Ghallab, S., Abdullah, M., Abuyassin, B., Vishwakarma, R., & Bouchama, A. (2023). Classic heat stroke in a desert climate: A systematic review of 2632 cases. *Journal of internal medicine*, 294(1), 7-20. Available at: 10.1111/joim.13633.



## Optimizing Topical Formulations from Natural Sources for a Safe and Healthy Shaving Experience in Hajj

Mohammed A.S. Abourehab<sup>1\*</sup>, Usama F Ali<sup>2</sup> and Abu Bakr Madyan<sup>3</sup>

1 -Pharmaceutical Sciences, College of Pharmacy, Umm Al-Qura University. Makkah, KSA, 2 -Pharmaceutics and Industrial Pharmacy Department, Faculty of Pharmacy, Minia University, Minia, Egypt, 3- Microbiology Department, College of Pharmacy, Derayah University, Egypt.

\*Corresponding author: E-mail (maabourehab@uqu.edu.sa)

### تحسين التركيبات الموضعية من المصادر الطبيعية لتجربة حلاقة آمنة وصحية في الحج

محمد عبد الوهاب أبو رحاب<sup>1\*</sup>، أسامة فرغلي علي حسن<sup>2</sup>، أبو بكر مدين<sup>3</sup>

1- قسم العلوم الصيدلانية، كلية الصيدلة جامعة أم القرى، مكة – المملكة العربية السعودية، 2- قسم الصيدلانيات والصيدلة الصناعية، كلية الصيدلة، جامعة المنيا، المنيا – مصر، 3- قسم الكائنات الدقيقة، كلية الصيدلة، جامعة دراية، المنيا – مصر.

#### الملخص

الحج هو أكبر تجمع سنوي للمسلمين في جميع أنحاء العالم، ويقام في مكة المكرمة بالمملكة العربية السعودية. تهدف رؤية السعودية 2030 إلى استضافة حوالي 30 مليون حاج كل عام بحلول عام 2030. تعد الحلاقة وتقصير الشعر من الجوانب الحاسمة في الحج والعمرة، وهي ضرورية لإكمال المناسك. ومع ذلك، فإن الممارسات غير السليمة أو غير الآمنة أو غير الصحية أثناء هذه الأنشطة يمكن أن تؤدي إلى إصابات في فروة الرأس ومشاكل صحية، مما يعزز انتشار الأمراض والحالات الجلدية. أصبحت الحلاقة العشوائية مصدر قلق كبير للصحة العامة على مر السنين، وتتطلب اهتمامًا مستمرًا من مختلف القطاعات في المملكة العربية السعودية. ويتم تشجيع الحجاج على استخدام عبوات الحلاقة الصحية ذات الاستخدام الواحد مع أدوات خاصة.

تهدف هذه الدراسة إلى إعداد تركيبة موضعية مُحسَّنة متعددة الأغراض تعتمد على مكونات طبيعية لحماية فروة الرأس من التأثيرات المختلفة بعد قص الشعر أثناء الحج والعمرة في مكة المكرمة. تم استخدام منتجات طبيعية مختلفة لصياغة التركيبات الموضعية. أظهرت النتائج فعالية مطهرة ومضادة للالتهابات، مما يدعم تطبيق التركيبة المثالية بعد قص الشعر والحلاقة. الكلمات الدالة: حج، حلاقة عشوائية، قص شعر، موضعي، مطهر، منتجات طبيعية.

#### Abstract

Hajj is the biggest annual gathering of Muslims worldwide, taking place in Makkah Almukaramah, Saudi Arabia. The Saudi Vision 2030 aims to host about 30 million pilgrims each year by 2030. Shaving and shortening hair are crucial aspects of Hajj and Umrah, essential for completing the rituals. However, improper, unsafe or unhygienic practices during these activities can lead to scalp injuries and health issues, fostering the spread of diseases and skin conditions. Random shaving has become a significant public health concern over the years, demanding continuous attention from various sectors in Saudi Arabia. Pilgrims are encouraged to use disposable hygienic shaving packages with special tools.

This study aims to prepare an optimized multi-purpose topical formulation based on natural constituents to protect the scalp from different effects after hair cutting for Hajj and Umrah in Makkah. Various natural products were used to formulate topical formulations. The results demonstrated potent antiseptic and anti-inflammatory activities, supporting the application of the optimized formula after hair-cutting and shaving.

**Keywords:** keyword, Hajj, random shaving, haircut, topical, antiseptic, natural products

### 1. Introduction

The Hajj is one of the largest and most geographically, ethnically, and culturally diverse annual mass gatherings in the world, attended by more than 2 million pilgrims from all over the world (1,2). Saudi Arabia, through the 2030 Vision and the 2020 National Transformation Program, expects the number of pilgrims and visitors to increase to an average of 30 million by 2030. Over the years, the Hajj has been a significant public health challenge posed by mass gatherings that requires endless attention from several government and nongovernment sectors in Saudi Arabia.

Shaving and hair shortening are considered one of the main duties of Hajj and Umrah for the pilgrim to complete their rituals. The Municipality of the Holy Capital, pays attention to this aspect, it prepares hygienically equipped barber shops distributed in different sites in Makkah; and it adopts the "Safe Shaving" campaign to prevent the spread of infectious diseases. Despite the tremendous efforts, there is a negative phenomenon that hinders and aborts these efforts, it is the phenomenon of "Random Shaving" (3). Several health hazards including communicable diseases and skin conditions are associated with Barbers' profession to which their visitors are exposed. There are many health risks that pilgrims can be exposed to, as tools and everything that comes into direct contact with the skin during the shaving process are the most important sources of these risks (4,5). Bad practices can result in some injury to the scalp and will promote and increase the risk of blood-borne infections (6). Excessive scalp wounds with the added risk of poor personal hygiene create ideal environment for skin infections and wound contamination. Most of the pilgrims shave their hair by licensed barber (70.6%), while 13.5% showed scalp wounds (7). Health risks can be classified according to the causes and methods of transmission into: viral, bacterial, fungal or parasitic pathogens (8). Recently, with the spread of awareness programs, the health awareness of pilgrims has begun to increase, where, they are encouraged to use a disposable hygienic shaving package that includes a comb, shaving gel, plastic apron, medical swab, razor, hand glove and barber mask.



Figure 1. Photos for real random shaving

Herbal medicine or natural based products are gaining importance for treating many diseases due to their significant effect and lesser side effects as compared to conventional medicines (9). Essential Oils are secondary metabolic products

found in various parts of plants; they are primarily used for treating skin infections (62%), skin inflammation (20%) and general skin maintenance (18%) (10). Nanoemulgel formulation solves the disadvantages of both nanoemulsion and hydrogel. Where, hydrophobic compounds can be incorporated first into the oil phase of a nanoemulsion and then adding them to the gel base. (11).

In this research, a number of effective antimicrobial agents of natural origin were employed. Tea tree oil (12-15), coriander oil (16-19) and rosemary oil (20-23) have strong antimicrobial effect against wide range of bacteria and fungi. The second problem that is commonly occurring during shaving is wounding. To ensure rapid healing of wounds many agents were used in this trial. Among wound healers, Hyaluronic acid (24-26). In addition, Aloe Vera extract (27-30) and honey (31-33) were also applied due to their high healing potential. The third problem associated with shaving is inflammation or Scalp folliculitis. To overcome any developed inflammations, chamomile extract was employed (34-35). The aim of this work is to prepare and characterize an optimized formula in the form of pharmaceutical emulgel to be used by pilgrims directly after shaving or shortening.

## 2. Methodology (Materials and methods)

### Materials and Reagents

Tea tree oil, coriander oil, Sesame oil, Rosemary oil and Honey were purchased from a local supplier. Chamomile extract, Aloe vera extract were purchased from IHerb online sit. Carbopol 934, Hyaluronic acid sodium salt, Vitamin E, Ethyl alcohol, Chlorhexidine, Panthenol and Polysorbate 80 were purchased from (Sigma-Aldrich, Germany). Media were purchased from (Himedia, India); other reagents were used without further treatment.

### Formulation of the Nanoemulsion System

The blend of the oils was prepared by mixing the accurately measured predetermined amount of each oil and oil soluble ingredients in a beaker with gentle mixed for 30 min using a magnetic stirrer. Using a predetermined ratio, the calculated quantities of polysorbate 80, water and water soluble ingredients were added in a beaker and blended for 30 min using a magnetic stirrer. Both oil and aqueous phase were separately heated to 70-80 °C then oil phase was added to the aqueous phase with constant stirring until cooling to room temperature using homogenization. The composition of Optimized Nanoemulsion Formulation was illustrated in Table 1.

### Preparation of Emulgel

The gel formulation were prepared using carbopol 934 as gelling agent. Gel base was prepared by dispersing Carbopol 934 in preheated distilled water at constant stirring at 100 rpm using mechanical shaker, then the pH was adjusted to 6-6.5 by adding drops of triethanolamine. The prepared dispersion was cooled and left overnight. The Composition of Optimized Gel Formulation was illustrated in Table 2.

The prepared emulsion and gel formulation were mixed in the ratio of 1:1 and homogenized using Ultra Turrax 18 at 2000 rpm for 60 minutes to get uniform emulgel.

Table 1: Composition of Optimized Nanoemulsion Formulation

Ingredient	Conc. (gm)
Oil blend	2
Polysorbate 80	3.75
Chamomile extract	0.5
Aloe vera extract	0.5
Honey	2

Glycerin	1
Panthenol	0.5
Vitamin E	0.5
Chlorhexidine	0.3
Hyaluronic	0.2
Perfume	q.s.
water	100

Table 2: Composition of Optimized Gel Formulation

Ingredient	Conc. (gm)
Carbopol 934P	1.00
PEG 400	10.75
Methyl paraben	0.03
Propyl paraben	0.01
Triethanolamine	q.s
water	100

1- Physical appearance: The prepared emulgel formula was inspected visually for their color, appearance, phase separation, homogeneity, texture and consistency.

2- pH measurement: The pH of the prepared emulgel was measured using digital pH meter. The measurement of the pH of each formulation was done in triplicate and average values were calculated.

3- Determination of Viscosity: The viscosity of the emulgel was determined at 25±1°C using the Brookfield Digital viscometer-LV DVE.

4- Spreadability measurement: The spreadability of the sample was evaluated in triplicate using an apparatus suggested by Mutimer. Spreadability is expressed in terms of time in seconds taken by two slides to slip off from emulgel and placed in between the slides under the direction of certain load.

Spreadability was measured in terms of g.cm/sec. Sample was tested for three times.

5- Extrudability measurement: The method adopted for evaluating emulgel formulation for extrudability which was based upon the determination of weight required to extrude 0.5 cm ribbon of emulgel in 10 sec. from lacquered collapsible aluminum tube. The extrudability was than calculated by using the following formula:

$$\text{Extrudability} = \text{Applied weight to extrude gel from tube (gm)} / \text{Area (cm}^2\text{)}$$

6- Skin irritation potential (in vivo): The irritancy potential of the prepared emulgel was carried out in healthy adult male albino rats. The results were interpreted as numerical scores for each animal as follows. 0 = no visible reaction. 1 = mild erythema. 2 = intense erythema. 3 = intense erythema with edema. 4 = intense erythema with edema and vesicular erosion. The scores for treatment group and control group animals were then compared.

7- Droplet Size Measurement and Polydispersity Index (PDI): Droplet size is typically determined using the Dynamic Light Scattering (DLS) approach using Zetasizer NANO ZS90. The polydispersity index (PDI) measurement provides information on the droplet size homogeneity within the prepared nanoemulsion. Sample was added to the cell and the mean droplet diameter and distribution was obtained.

8- Zeta Potential: Zeta potential for the prepared emulgel was determined using Zetasizer NANO ZS90. Sample was injected to the specific photocell and the mean zeta potential was measured.

9- Antibacterial activity: Three standard strains of microorganisms were used in this study. Each formulation was assessed for its antimicrobial activity against the microorganisms on a nutrient agar plates using a suitable diffusion method. Ciprofloxacin was used as positive control. The zone of inhibition was checked and recorded.

10- Anti-fungal Study: Test Organism used *Candida albicans* (Clinical isolate). Sabouraud Dextrose Agar (SDA) was used as culture medium. The medium was prepared as specified by the manufacturers. Ketoconazole was used as the positive control. After incubation the petri plates were observed for the zone of inhibition. The diameter of zone of inhibition was reported in mm.

11- Statistical Studies: All the obtained data from different treated groups and the control group were compared utilizing a one-way analysis of variance (ANOVA). All values are expressed as mean  $\pm$  standard deviation (SD). The difference between the control and the treatments was considered statistically significant at  $p < 0.05$ .

**3. Results and Discussion** The results of various physical parameters evaluated are given in Table (3). All parameters were found to be within the acceptable ranges.

Table 3. Characterization of the Optimized Emulgel Formulation

Parameter	Result (mean $\pm$ SD)
Appearance	Creamy white
Texture	Smooth
Homogeneity	Homogenous
Consistency	Semisolid
Phase separation	No
pH	6.19 $\pm$ 0.27
Viscosity at 10 rpm	13670
Viscosity at 20 rpm	8140
Viscosity at 50 rpm	5350
Spreadability $\gamma$ (gm.cm/sec)	22.34 $\pm$ 1.56
Extrudability (gm/cm <sup>2</sup> )	16.28 $\pm$ 0.54 (Excellent)
Droplet size (nm)	118.7 $\pm$ 52.39
Polydispersity Index (PDI)	0.145
Zeta potential (mV)	-24.4 $\pm$ 5.83

1. **Physical Appearance**: The results indicated that the formulated emulgel was creamy white in color, homogenous without grittiness; having semisolid consistency. No phase separation in emulgel. The obtained nanoemulsion, gel formulations and the optimized Nanoemulgel are represented in Figure (2).

2. **pH determination**: The pH of human skin is known to be between 4.5 and 6. The pH values of the emulgel formulation was 6.19  $\pm$  0.27, which lies within the normal pH range of the skin and compatible with the skin, hence would not cause any skin irritation.

3. **Viscosity determination**: The viscosity of the emulgel during handling, transport and storage is the most important criteria and a crucial parameter for effective application to the skin.

The rheological behaviour of the prepared emulgel showed non-Newtonian shear thinning pseudo plastic type of flow, viscosity decreases in as the shear rates increasing. As the applied shear is increased, the hydrophobic interactions are



not able to keep the fluid-filled microstructures together. This results in the transition of the system from the gelled phase to the free-flowing liquid phase, marked by the disruption of the 3-dimensional networked structures.

4. Spreadability values: The ease with which the topical preparations spread over the application site on the skin and the affected area is referred to as spreadability. The therapeutic efficacy of the topical formulation may be directly affected by its spreadability.

The results of spreadability values were reported in Table 3. From the result obtained it was observed that the emulgel formulation shows spreading coefficient of  $22.34 \pm 0.56$  (gm.cm/sec) which may be due to presence of optimum concentration of gelling agent.

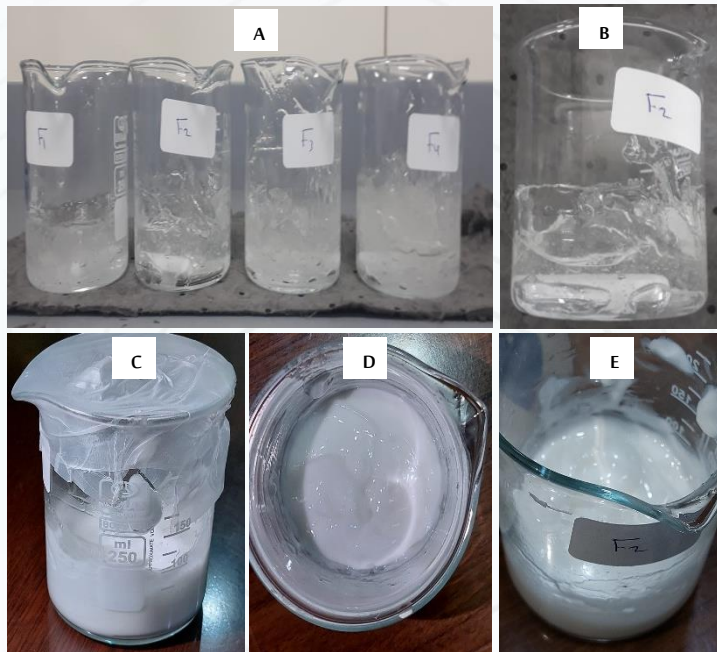


Figure (2): Photos for the prepared systems: A: Prepared Gels B: Optimized gel formula C, D and E: Optimized Emulgel Formula

5. Extrudability study: It is a usual official test to measure the force required to extrude the formulation from package material tube, it depends upon the viscosity of that formulation. As the viscosity of the preparation decreased, the required force decreased showing better extrudability. The extrudability of the prepared emulgel was found to be  $16.28 \pm 0.54$  gm/cm<sup>2</sup>, which means a little pressure required to be applied on tube which lead to better patient compliance and indicated that the formulation has an excellent extrudability.

6. Skin Irritation study: All treated rats with selected emulgel formulation demonstrated no symptoms of allergy like inflammation, redness, irritation on rats over the period of to 24 h. This indicates the compatibility and safety of the formulated emulgel.

7. Droplet Size and Polydispersity Index (PDI): The results for droplet size distribution and PDI are showed in Table3 and Figure 3. The obtained result reveals that nanoemulsion have droplets with the average diameter of  $118.8 \pm 52.39$  nm, and PDI of 0.145. Results indicates the uniformity in the droplet size distribution of within the optimized nanoemulgel.

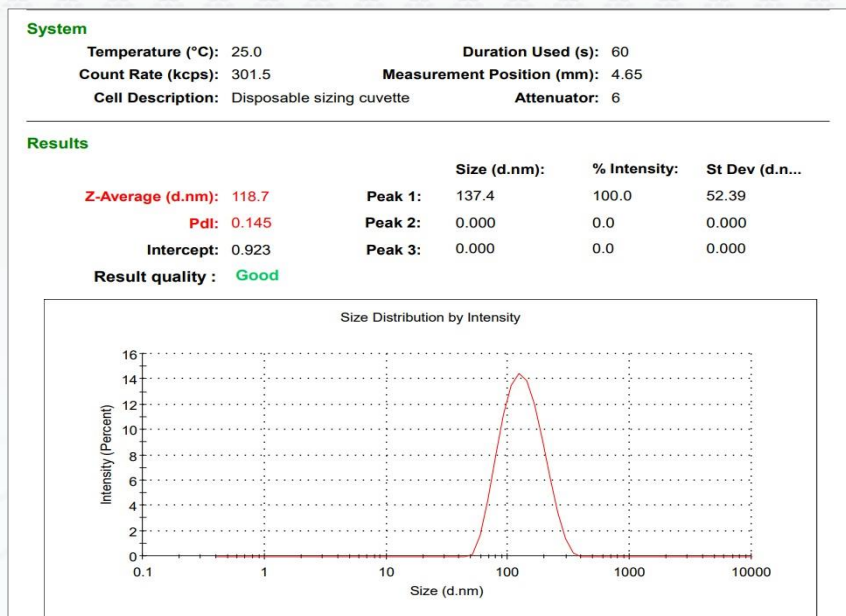


Figure 3. Droplet size distribution and PDI

8. Zeta Potential: As nanoemulgel is made from nanoemulsion and a gelling agent, the formulation can acquire an electrical charge. Emulsion stability is directly related to the magnitude of the surface charge. Where, high electrical repulsive forces among nanoemulsion droplets prevents coalescence, while, on the contrary, a decrease in electrostatic repulsive forces causes phase separation. The obtained results are illustrated in Table 3 and Figure 4. The results revealed that the zeta potential is  $-24.4 \pm 5.83$  mV, the negative charge on the optimized formula may be attributed to the presence of an anionic group of fatty acids and glycols in the formula components.

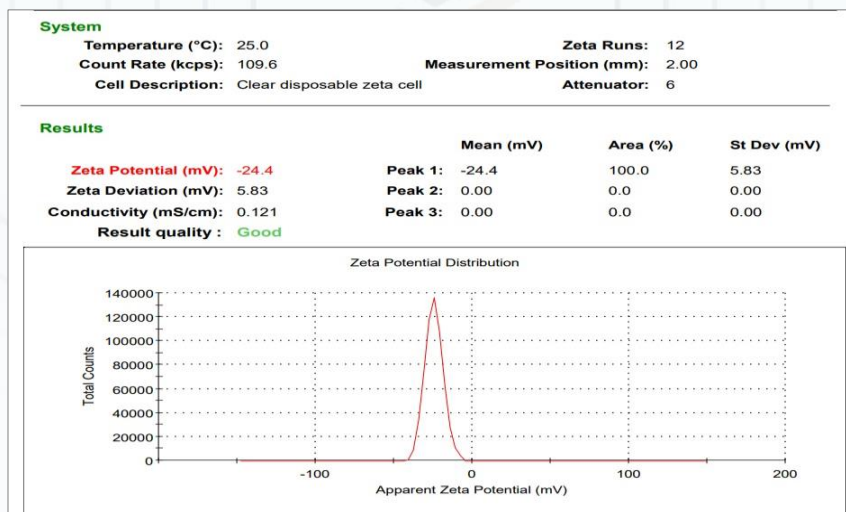


Figure 4. Zeta potential Results

9. In vitro antimicrobial Studies: The antibacterial activity showed (Table 4) that the zone of inhibition exhibited by the prepared emulgel was significantly comparable ( $p < 0.05$ ) to that of the standard drug (ciprofloxacin for all the utilized

microorganism strains. These results are in agreement with previous results related to the different components of the formulated emulgel.

Table 4: Antimicrobial activity of prepared emulgel against different microbial strains. Data expressed as (mean ± SD).

Tested Formulation	Zone of Inhibition (mm)		
	<i>Pseudomonas aeruginosa</i> (ATCC – 5442)	<i>E. coli</i> (Clinical isolate)	<i>Staphylococcus aureus</i> (ATCC- 25923)
Ciprofloxacin	18.9± 0.3	15.9±0.6	17.2±0.4
Emulgel	18.2± 0.4	15.4±0.5	18.3±0.3

10. In vitro Antifungal Studies: Anti-fungal Study shows (Table 5) that the zone diameter of standard ketoconazole and formulated emulgel are comparable, and the formulated emulgel is more effective in inhibiting the growth of the *Candida albicans* species. This result is in agreement with results obtained from previous studies related to the components of the emulgel.

Table 5: Antifungal activity of prepared emulgel against *Candida albicans* strain. Data expressed as (mean ± SD).

Tested Formulation	Concentration (µg/ml)	Zone of Inhibition (mm)
Ketoconazole	50	18.2± 0.7
Emulgel	50	19.5± 0.5

#### 4. Conclusions

Thus, results of the current study clearly indicated a promising potential of the prepared emulgel as an antiseptic and antibacterial for scalp after shaving or hair cutting.

#### 5. Recommendations

The use of the prepared emulgel after shave and hair cutting in barber shops to face the hazards of infectious disease transmission in Hajj and Ummrah.

#### References

- 1-Alotaibi BM, Yezli S, Bin Saeed AA, Turkestani A, Alawam AH, Bieh KL. (2017). Strengthening health security at the Hajj mass gatherings: characteristics of the infectious diseases surveillance systems operational during the 2015 Hajj. *J Travel*. 24(3).
- 2- Memish ZA. (2013). Hajj and the public health significance of mass gatherings. *East Mediterr Health J*; 19 Suppl 2:S5-6.
- 3- Omar B Ahmed, Atif H Asghar, Bassam H. Mashat, Ibrahim HA Abd El-Rahim, Hegazy AI. (2014). Occurrence of Fungal Contamination due to Unhealthy Haircutting during Hajj. *International Journal of Science and Research*. 3 (12): 748-750. Paper ID: SUB14559
- 4- Al-Rabeei NA, Al-Thaifani AA, Dallak AM. (2012). Knowledge, attitudes and practices of barbers regarding hepatitis B and C viral infection in Sana'a city, Yemen. *J Community Health*. 37 (5): 935-9. doi: 10.1007/s10900-011-9535-7.
- 5- Saad A. (2017). Health issues during Hajj. *Cairo: The Egyptian Journal of Internal Medicine*.
- 6- Silverberg N.B, Weinberg J.M, De Leo V.A. (2002). Tinea capitis: focus on African American women. *J. Am. Acad. Dermatol*. 46 (Suppl 2): 120-124.
- 7- Fahad S. Al-Jasser, Ibrahim A. Kabbash, Mohammad A. AlMazroa, Ziad A. Memish. (2023). Patterns of diseases and preventive measures among domestic hajjis from Central, Saudi Arabia. *Eastern Mediterranean Health Journal*. Vol. 19 Supplement 2. S41- S34.
- 8- Mohamed Mutocheluh and Kwaku Kwarteng. (2015). Knowledge and occupational hazards of barbers in the transmission of hepatitis B and C was low in Kumasi, Ghana. *Pan African Medical Journal*. 20:260

- 9- Ganesan V, Kaithavalappil S S, Kannappan M and Vasudevan D T (2014). *Asian J. Res. Pharm Sci. Biotechnol.* 47–54
- 10-Do, T.K.T.; Hadji-Minaglou, F.; Antoniotti, S.; Fernandez, X. (2015). Authenticity of essential oils. *Trends Anal. Chem.* 66, 146–157.
- 11-Eid AM, El-Enshasy HA, Aziz R, et al. (2014). Preparation, characterization and anti-inflammatory activity of *Swietenia macrophylla* nanoemulgel. *J Nanomed Nanotechnol.* 5(2):1–10.
- 12-Federico Iacovelli, Alice Romeo, Patrizio Lattanzio, et al. (2023). Deciphering the Broad Antimicrobial Activity of *Melaleuca alternifolia* Tea Tree Oil by Combining Experimental and Computational Investigations, *Int. J. Mol. Sci.* 24, 12432
- 13-Hammer, K. A., L. Dry, M. Johnson, E. M. Michalak, C. F. Carson, and T. V. Riley. (2003). Susceptibility of oral bacteria to *Melaleuca alternifolia* (teatree) oil in vitro. *Oral Microbiol. Immunol.* 18:389-392.
- 14-Carson, C.F., Hammer, A., Riley, T.V. (2006). *Melaleuca alternifolia* (Tea Tree) Oil: a Review of Antimicrobial and Other Medicinal Properties. *Clinical Microbiology Reviews*, Jan. 2006, p. 50–62.
- 15-Hammer, K. A., C. F. Carson, and T. V. Riley. (2002). In vitro activity of *Melaleuca alternifolia* (tea tree) oil against dermatophytes and other filamentous fungi. *J. Antimicrob. Chemother.* 50:195-199.
- 16-Samina Amin, Ab Cd and Arif Malik. (2021). Antimicrobial Activity of Coriander sativum. *Journal of Pharmaceutical Research International* 32(48):74-81
- 17-Filomena Silva, Fernanda C Domingues, (2015). Antimicrobial Activity of Coriander Oil and Its Effectiveness as Food Preservative, *Critical Reviews In Food Science and Nutrition*, 57(1).
- 18-Delaquis RJ, Stanich K, Girard B, Massa G. (2002). Antimicrobial activity of individual and mixed fractions of dill, cilantro, coriander and eucalyptus essential oils. *Int J Food Microbiol*; 74: 101-9.
- 19-Lalitha V, Kiran B, Raveesha KA. (2011). Antifungal and antibacterial potentiality of six essential oils extracted from plant source. *Int J Eng Sci Technol*; 3: 3029-38.
- 20-Hussain Al, Anwar F, Chatha SA, et al. (2010). *Rosmarinus officinalis* essential oil: antiproliferative, antioxidant and antibacterial activities. *Braz J Microbiol.* 41(4):1070–1078.
- 21-Silva NCC, Fernandes Júnior A. (2010). Biological properties of medicinal plants: a review of their antimicrobial activity. *The Journal of Venomous Animals and Toxins including Tropical Diseases.* 16(3):402–413.
- 22-Kwiatkowski P, Giedrys-Kalemba S, Mizielińska M, et al. (2015). Antibacterial activity of rosemary, caraway and fennel essential oils. *Herba Polonica.* 61(4):31–39.
- 23-Faleiro ML. (2013). The mode of antibacterial action of essential oils. In: Méndez-Vilas A, editor. *Microbial pathogens and strategies for combating them: science, technology and education.* Spain: Formatex Research Center. p. 1143–1156.
- 24-Manuela G Neuman, Radu Nanau, Loida Oruña-Sanchez, Gabriel Coto. (2015). Hyaluronic Acid and Wound Healing, *Journal of Pharmacy & Pharmaceutical Sciences*, 18 (1):53-60.
- 25-Richard D. Price, Simon Myers, Irene M. Leigh and Harshad A. Navsaria, (2012). The Role of Hyaluronic Acid in Wound Healing, *American Journal of Clinical Dermatology.* Volume 6, pages 393–402.
- 26-Charles J. Doillon, Frederick H. Silver. (1986). Collagen-based wound dressing: Effects of hyaluronic acid and firponectin on wound healing, *Biomaterials*, Volume 7, Issue 1, Pages 3-8
- 27-Seyyed Abbas Hashemi, Seyyed Abdollah Madani and Saied Abedian kenari, (2015). The Review on Properties of Aloe Vera in Healing of Cutaneous Wounds, *BioMed Research International.* Article ID 714216, 6 pages
- 28-Wang, Y.; Zhang, Y.; Lin, Z.; Huang, T.; Li, W.; Gong, W.; Guo, Y.; Su, J.; Wang, J.; Tu, Q. (2021). A green method of preparing a natural and degradable wound dressing containing Aloe vera as an active ingredient. *Compos. Part B Eng.* 222, 109047.
- 29-Mariana Chelu, Adina Magdalena Musuc, Monica Popa and Jose Calderon Moreno. (2023). Aloe vera-Based Hydrogels for Wound Healing: Properties and Therapeutic Effects. *Gels.* 9, 539
- 30-Zahra Molazem1, Fatemeh Mohseni2, Masoumeh Younesi3 and Sareh Keshavarzi. (2015). Aloe Vera Gel and Cesarean Wound Healing: A Randomized Controlled Clinical Trial, *Global Journal of Health Science*; Vol. 7, No. 1.
- 31-Noori S Al-Waili, Khelod Salom, Ahmad Al-Ghamdi. (2011). Honey for Wound Healing, Ulcers, and Burns; Data Supporting Its

Use in Clinical Practice. *The Scientific World Journal* 11(1):766-87

32-Hana Scepankova, Patricia Combarros-Fuertes, Fresno JM, Leticia M. Estevinho. (2021). Role of Honey in Advanced Wound Care. *Molecules* 26(16):4784

33-Gethin G, Cowman S. (2005) Case series of use of Manuka honey in leg ulceration. *Int Wound J*. 2(1):10–5.

34-Yun-Lei Dai, Ying Li, Qi Wang, Feng-Jv Niu, Kun-Wei Li, Yun-Yu Wang, Jian Wang, Chang-Zheng Zhou, Li-Na Gao. (2023). Chamomile: A Review of Its Traditional Uses, Chemical Constituents, Pharmacological Activities and Quality Control Studies, *Molecules*. 28(1): 133.

35-Paola DeCicco, Giuseppe Ercolano, Carmina Sirignano, Valentina Rubino, Daniela Rigano, Angela Ianaro, Carmen Formisano. (2023) Chamomile essential oils exert anti-inflammatory effects involving human and murine macrophages: Evidence to support a therapeutic action, *Journal of Ethnopharmacology*, Volume 311, 116391



## Nutritional Knowledge and Status Among Hajj Pilgrims and Umrah Visitors

Walaa E Alhassani <sup>1\*</sup>, and Bayan M Tashkandi<sup>2</sup>

1- Department of Clinical Nutrition, Umm Al-Qura University, 2- Department Food and Nutrition, King AbdulAziz University.

\*Corresponding author: E-mail (wehassani@uqu.edu.sa)

### المعرفة الغذائية والحالة الغذائية بين الحجاج والمعتمرين

ولاء بنت عصام الحساني<sup>1\*</sup>، وبيان بنت منصور طاشكندي<sup>2</sup>

1- قسم التغذية الإكلينيكية، جامعة أم القرى، 2- قسم الغذاء و التغذية، جامعة الملك عبد العزيز.

#### المخلص

الخلفية العلمية: تتشرف المملكة العربية السعودية بخدمة الملايين من المسلمين من مختلف الجنسيات والأعراق والثقافات من شتى أنحاء العالم سنوياً. يهدف هذا البحث إلى دراسة تأثير العوامل العرقية والديموغرافية على المعرفة الغذائية والحالة التغذوية لدى الحجاج والمعتمرين.

الطريقة: تم إجراء استطلاع عرضي على 237 من الحجاج والمعتمرين من الجنسين والناطقين باللغة العربية أو الإنجليزية خلال موسمي الحج والعمرة. تم تقييم الحالة التغذوية والمعرفة الغذائية من خلال استبيان موثوق ومُعتمد.

النتائج: أظهرت الدراسة وجود دلالة معنوية بين الحالة التغذوية والمعرفة الغذائية بين المشاركين. كما أوضحت اختلاف مستوى المعارف الغذائية بناء على تنوع الخلفيات العرقية والبيانات الديموغرافية للحجاج والمعتمرين.

أهمية الدراسة على المملكة العربية السعودية: تعتبر هذه الدراسة ذات أهمية خاصة للمملكة العربية السعودية لتوفير رؤى أساسية لإدارة الصحة العامة، حيث تحدد مجموعة من الاحتياجات الغذائية وتسد فجوات المعرفة بين الحجاج والمعتمرين. والذي يساهم في تخصيص موارد الرعاية الصحية والاستعداد للطوارئ بكفاءة خلال موسمي الحج والعمرة. كما تساهم في تعزيز رضا الحجاج وتجربتهم الإجمالية من خلال إثراء استراتيجيات الصحة والتغذية من خلال مقدمي خدمات التغذية والإعاشة خاصة مراعية الفروق الثقافية والعرقية. من خلال معالجة هذه المجالات الرئيسية، يمكن للمملكة العربية السعودية تعزيز قدرتها وسمعتها في إدارة الحشود بفعالية، مما يعزز رفاهية ضيوف الرحمن ويضمن تجربة حج و عمرة أكثر تميزاً وأماناً وإرضاءً.

#### Abstract

**Background:** The annual Islamic pilgrimages of Hajj and Umrah attract millions of Muslims from diverse ethnic and cultural backgrounds. This study investigates how ethnic and demographic factors influence pilgrims' nutritional knowledge (NK) and status .

**Methods:** A cross-sectional survey was conducted on 237 participants Arabic and/or English speakers during Hajj and Umrah. The NK was assessed via a questionnaire. Also, nutritional status (NS) was recorded .

**Results:** The findings present an insightful overview of the NK and status of the subjects. The data reflect a wide array of nutritional perspectives and practices influenced by the pilgrims' diverse ethnicities and demographic profiles .

**Implications for the Kingdom of Saudi Arabia (KSA):** This study is particularly significant for the country. It provides essential insights for public health management, identifying nutritional needs and knowledge gaps among international pilgrims. This understanding is crucial for efficiently allocating healthcare resources and emergency preparedness during these large-scale gatherings. Furthermore, the study's findings have the potential to enhance pilgrim satisfaction and overall experience by informing culturally sensitive and inclusive health and nutrition strategies. By addressing these key areas, the KSA can reinforce its capability and reputation in effectively managing significant global religious events, ultimately promoting the well-being of pilgrims and ensuring a safer, more fulfilling pilgrimage experience.

**Keywords:** pilgrims, Umrah visitors, Nutritional knowledge, Hajj

## 1. Introduction

Every year, millions of Muslims visit the holy city of Makkah in Saudi Arabia (SA) for Umrah and Hajj. Studies have shown that these visitors are predominantly elderly, obese, less active, and often have multiple health conditions and medications (Yezli, 2023). This demographic profile highlights the need for targeted studies to inform policymakers in SA. Factors such as mass gatherings, hot weather, and high physical activity during these pilgrimages can lead to various health problems. Additionally, Muslims from diverse countries bring different dietary habits and levels of nutritional knowledge (NK), which are crucial for their health and well-being before, during, and after their worship.

Understanding the impact of NK on visitors' health and safety is essential. For instance, specific dietary management is required for those with long-term conditions like Diabetes Mellitus (DM) and Hypertension (HTN). The significant physical activity and environmental stressors associated with pilgrimage can be mitigated through proper NK, helping to maintain health and energy levels. Furthermore, the congregation of large crowds increases the risk of foodborne illnesses and the transmission of contagious diseases, emphasizing the need for well-planned risk management strategies (Marglani et al., 2016).

To our knowledge, there has been no specific study investigating the NK and knowledge among Hajj pilgrims and Umrah visitors. However, global research indicates a general poor NK. For example, studies in Egypt, Syria, SA, and Jordan have highlighted the need for nutrition education to improve general health and NK (Bany-yasin et al., 2023). Research among Syrian and Jordanian students also identified a lack of NK as a significant barrier to healthy nutrition (Musaiger et al., 2012). Observations of poor NK in various countries have been reported (Dickson-Spillmann & Siegrist, 2011; Koch et al., 2021), which could interfere with managing health problems and maintaining good eating habits (Karamravan et al., 2014). Furthermore, NK has been linked to body weight management. A study reported that high NK led to more weight loss among overweight and obese low-income mothers (Klohe-Lehman et al., 2006).

High body mass index (BMI) significantly increases the risk of diseases like DM, HTN, and Dyslipidemia (Knight, 2011), and is associated with mortality (Fontaine et al., 2003). Studies assessing BMI among Muslims traveling to Makkah reported that among 419 Algerian pilgrims (30% suffering from diseases), the average BMI was  $26.9 \pm 4.5$ , with 48.9% being overweight and 17.4% obese (Alkhairi et al., 2019). Similarly, another study found that among adult pilgrims from 59 nationalities, 23.56% were overweight and 28.57% obese (Alshehri et al., 2021).

Given that visiting Makkah is often a once-in-a-lifetime goal for Muslims (Alzeer, 2009), it's crucial to study this spiritual journey comprehensively, including aspects of nutrition. Improving nutrition and promoting nutrition education and awareness are high priorities for the Saudi government for Hajj pilgrims and Umrah visitors. Therefore, this study aims to investigate how ethnic and demographic factors influence pilgrims' NK and status.

## 2. Methodology

**Study Design:** A cross-sectional survey study was conducted through face-to-face interviews with pilgrims at King Abdulaziz, Al Noor, and King Faisal hospitals in Makkah during the Hajj season. These hospitals cater specifically to Hajj pilgrims. Additionally, an electronic questionnaire was distributed to Umrah visitors via the WhatsApp application during the Umrah season of 2023, targeting groups both inside and outside the Holy Mosque in Makkah. The study commenced in July 2019 and concluded in November 2023, with a temporary suspension during the COVID-19 pandemic years of 2020 and 2021. Informed consent was obtained from all the participants and the research was done under the supervision of the research committee of the Saudi ministry of health. logistic support was provided by Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research.

**Data Collection:** For the study, 237 adult inpatients and outpatients, Hajj pilgrims and Umrah visitors, were recruited. Self-reported anthropometric measurements such as body weight and height were used, and body mass index (BMI) was calculated. Participants completed the questionnaire (written in both languages Arabic and English) that included questions related to their demographic data (gender, You in Makkah for, nationality, age group, social status, level of education, current job, and BMI) and NK. The revised General Nutrition Knowledge Questionnaire, which measures NK among different populations, was used (Alkhalidy et al., 2019; Husain et al., 2021; Kliemann et al., 2016; Mo'ath & Attlee, 2021; Parmenter & Wardle, 1999; Thompson et al., 2021). However, due to the questionnaire's length, some questions potentially relevant to unfamiliar dishes to the participants' home countries were omitted. This multiple-choice questionnaire comprises 64 questions, with each question presenting one correct answer alongside multiple incorrect options. The total score attainable is 64 points, with each correct answer contributing one point towards this total, indicative of the participant's comprehensive understanding. Conversely, selecting an incorrect answer yields zero points for that question.

**Statistical Analysis:** SPSS software version 25 (IBM Corp, Armonk, NY) used for statistical analysis. All values were presented as means ( $\pm$ SD). Differences between group means were calculated by one-way analysis of variance (ANOVA) followed by LSD test used. Pearson Chi-Square analysis was performed to test the differences between variables. All statistical analyses were performed at a significant level of 95% (P. value  $\leq$  0.05).

## 3. Results

Two hundred thirty-seven pilgrims and Umrah visitors were enrolled in the current study. shows in Table 1 the socio-demographic data of the participants. The numbers of males and females who participated in the questionnaire were 69 and 168 respectively, 148 persons were came for hajj and 89 for Umrah. It's clearly noticed that the highest percentage of participants were from Arab countries and SA followed by South Asia represented 56.55%, 26.2% and 5.5% respectively. According to their age group 24.1% were older than 60 years old while 14.8% were less than 30 years old. The age of most study participants ranged from 60 and above and the majority were married 181 (76.4) %. According to participants education level, more than three quarter (82) % of them were educated 196 (82.7) %. High school, student college, bachelor's degree, postgraduate (higher education). Most of the participants worked in the private sector 80 (33.8) %. The majority of the study participants were overweight according to their body mass index as illustrated in Table 1. Additionally, the table shows that the majority of participants are free from Diabetes, Hypertension, Heart Disease, Kidney Disease, and Gastrointestinal Disease. However, (19)% are diagnosed with Diabetes and the same



percentage with Hypertension, (9)% with Heart disease, (8)% with Gastrointestinal Disease, and (4)% with Kidney Disease.

Table 1: Participant’s Socio-demographic Profile.

	Variables	Frequency (n=237)	% Percentage
Gender	Male	69	29.1
	Female	168	70.9
You in Makkah for	Hajj	148	62.4
	Umrah	89	37.6
Countries	Arab Countries	134	56.5
	Non-Arab African	7	3.0
	South Asia	13	5.5
	Southeast Asia	2	8.
	America	6	2.5
	Europe	2	8.
	Saudi	62	26.2
	Arab Gulf Countries	11	4.6
Age Group	Less than 30 years old	35	14.8
	39-30years old	47	19.8
	49-40years old	47	19.8
	59-50years old	51	21.5
	60years and older	57	24.1
Social Status	Single	38	16.0
	Married	181	76.4
	Divorced	7	3.0
	Widower	11	4.6
Level of Education	Illiterate	19	8.0
	Less than High school	22	9.3
	High school	44	18.6
	College student	14	5.9
	Bachelor's Degree	92	38.8
	Postgraduate	46	19.4
Current Job	Unemployed	33	13.9
	Private Sector	80	33.8
	Governmental Sector	41	17.3
	Housewife	53	22.4
	Retired	30	12.7
Diagnosed with	Diabetes Miletus	45	19
	Hypertension	45	19
	Heart Disease	22	9
	Kidney Disease	9	4
	Gastrointestinal disease	20	8
	BMI	7.33 ± 28.35	
	NK	36.3 ± 8.7	

BMI and NK present as mean and SD.

Association between BMI category of the subjects and their countries presented in Table 2. It shows a highly significant difference ( $P < 0.001$ ). The same trend was observed with the association between the BMI category of the subjects and their education level.

Table 2: Association Between BMI Category of Subjects and Their Countries and Education Level.

Variables	BMI Category*					P .Value	
	Normal	Overweight	Obese 1	Obese2	Over 40		
Countries	Arab Countries	39	42	33	12	8	0.000
	Non-Arab African	2	5	0	0	0	
	South Asia	2	5	6	0	0	
	Southeast Asia	0	2	0	0	0	
	America	1	1	0	0	4	
	Europe	1	0	1	0	0	
	Saudi Arabia	23	27	10	1	1	
	Arab Gulf Countries	7	3	1	0	0	
Education Level	Illiterate	4	2	5	5	3	0.005
	Less than High School	6	7	5	1	3	
	High School	10	18	13	1	2	
	College Student	8	4	1	0	1	
	Bachelor's Degree	28	36	21	4	3	
	Postgraduate	19	18	6	2	1	

\*Underweight (<18.5); Normal weight (18.5 -24.9kg/m<sup>2</sup>); Overweight (25.0-29.9kg/m<sup>2</sup>); Obesity Grade I (30.0-34.9kg/m<sup>2</sup>); Obesity Grade II (35.0-39.9kg/m<sup>2</sup>); and Extreme Obesity as BMI of ≥40 kg/m<sup>2</sup>

Mean ± SD of the total score of the subject knowledge according to their countries, education level and their age group displayed in Table 3. Mean ± SD of the total score of the knowledge of Southeast Asia was 43.5 ± 4.95 which was the highest score and nearly equal to that of Arab Gulf Countries. There were insignificant differences ( $p > 0.05$ ) between Saudi and America which were 38.468 ± 8.49 and 38.83 ± 5.49 respectively but significantly ( $P \leq 0.05$ ) higher than that of South Asia, Arab Countries, Europe, and Non-Arab Africa. According to the educational level of participants, the highest levels of total knowledge were observed in postgraduate and College students followed by bachelor's degrees represented 39.13 ± 8.88, 38 ± 8.37, and 37.53 ± 7.56 respectively while illiterate participants showed the lowest score with significant difference ( $P \leq 0.05$ ) represented 28.05 ± 8.24.

Table3: Mean ± SD of Total Score of Subject Knowledge According to Their Countries, Education Level and Their Age Group

Variables	Frequency	Mean ± SD of Total Score of Knowledge: 64	P value	
Countries	Arab Countries	134	35.067 ± 8.76 <sup>b</sup>	0.018
	Non-Arab African	7	31 ± 11.95 <sup>a</sup>	
	South Asia	13	35.077 ± 5.64 <sup>b</sup>	
	Southeast Asia	2	43.5 ± 4.95 <sup>c</sup>	
	America	6	38.83 ± 5.49 <sup>bc</sup>	
	Europe	2	31.5 ± 10.61 <sup>a</sup>	
	Saudi Arabia	62	38.468 ± 8.49 <sup>bc</sup>	
	Arab Gulf Countries	11	42.091 ± 7.23 <sup>c</sup>	
Education Level	Illiterate	19	28.05 ± 8.24 <sup>a</sup>	0.000

Less than High School	22	34.36 ± 5.47 <sup>b</sup>
High School	44	34.75 ± 10.12 <sup>b</sup>
College Student	14	38b ± 8.37 <sup>c</sup>
Bachelor's Degree	92	37.53 ± 7.56 <sup>bc</sup>
Postgraduate	46	39.13 ± 8.88 <sup>c</sup>

The same letter in the same collum shows insignificant difference.

Mean ± SD of the association between BMI Category of subjects and of total score of knowledge in Table 4. It shows no significant difference ( $P < 0.05$ ).

Table 4: Association Between BMI Category of Subjects and of total score of knowledge.

Variables	Frequency	Mean ± SD of total score of knowledge	P .Value
*BMI Category	Normal	75	36.77 ± 10.34
	overweight	85	36.91 ± 7.29
	Obese 1	51	35.04 ± 9.04
	Obese 2	13	34.38 ± 8.07
	over 40	13	36.46 ± 6.74

\*Underweight (<18.5); Normal weight (18.5 -24.9kg/m<sup>2</sup>); Overweight (25.0-29.9kg/m<sup>2</sup>); Obesity Grade I (30.0-34.9kg/m<sup>2</sup>); Obesity Grade II (35.0-39.9kg/m<sup>2</sup>); and Extreme Obesity as BMI of ≥40 kg/m<sup>2</sup>

#### 4. Discussion

This study aimed to investigate how ethnic and demographic factors influence pilgrims' NK and status. The data revealed a wide array of nutritional perspectives and practices, influenced by the pilgrims' diverse ethnicities and demographic profiles. Preliminary results indicate notable differences in nutritional understanding and dietary habits shaped by these factors.

Upon examining the NK scores of participants, we generally found poor knowledge 36 ±9 out of 64 points. This finding aligns with several global studies reporting similarly low NK levels using different questioner (Hakli et al., 2016; Mowe et al., 2008; Zaborowicz et al., 2016). During the short period of Hajj and Umrah, pilgrims experience increased physical activity and changes in dietary habits, which could negatively impact sick people, especially in those who suffer from diabetes mellitus (hypo or hyperglycemia). Also, it could lead to dehydration. Therefore, the Saudi Ministry of Hajj and Umrah and the Ministry of Health provide free health services through physicians, nurses, and pharmacists. The relevance of these health services becomes more apparent when examining the findings of a study conducted by Gaddoury et al. (2023). Among pilgrims, this study found a significant association between all-cause mortality during Hajj and conditions such as DM, HTN, and CVD. Addressing the healthcare needs of these patients can be costly. While higher education levels generally correspond to better NK, we observed that NK among the educated participants the score was better than illiterate. Similarly, a study by Yahia et al. (2016) assessing NK among college students found better knowledge, likely due to the positive impact of education on NK levels. NK is a significant factor influencing eating behavior and can lead to poor dietary choices and various health problems (Adriaanse et al., 2011; Miller et al., 2010). As pilgrims have diverse preferences and requirements, and it is unclear if they possess adequate NK to make right food choices based on their health and needs, it is advisable to include scientific descriptions and instructions in restaurants and grocery stores. Developing a website or smartphone app where pilgrims can access information about Saudi Arabian dishes, could be beneficial to know the ingredients of the food. Additionally, creating a more personalized menu selection

environment in restaurants might be helpful. Turkistani (2022) suggests using digital solutions and providing electronic food and nutrition services during visits to Makkah.

Secondly, when assessing the participants' NS using Body Mass Index (BMI), we found that overweight and obesity were prevalent. This finding aligns with Alkhairi et al. (2019), who reported that among 419 Algerian pilgrims (30% suffering from diseases), the average BMI was  $26.9 \pm 4.5$ , with 48.9% being overweight and 17.4% obese. Similarly, a study by Alshehri et al. (2021) found that among adult pilgrims from 59 nationalities, 23.56% were overweight and 28.57% obese. World Health Organization estimates indicate that, as of 2016, more than 1.9 billion adults aged 18 years and older were overweight and 650 million were obese, and projections for 2023 suggest more than 1.53 billion overweight and 573 million obese individuals (Kelly et al., 2008).

Numerous studies have identified overweight and obesity as major risk factors for conditions such as DM, HTN, and Dyslipidemia, and are associated with increased mortality (Aguirre et al., 2013; Biswas et al., 2019; Petrie et al., 2018; Pi-Sunyer, 2009; Seravalle & Grassi, 2017; Tiptaradol & Aekplakorn, 2012). Our results could assist Saudi authorities in recognizing that people who are overweight or obese may require special considerations, particularly regarding heat hypersensitivity and medical comorbidities like DM and CVD. Addressing these issues is crucial as the treatment of these diseases can be costly.

The association between excessive fat accumulation and education level is complex. In our study, when examining the correlation between overweight/obesity and education level, we were unable to discern a clear pattern due to the small sample size. However, a study investigating obesity prevalence among adults by education level found that 40.0% of individuals who were high school graduates or less were obese, compared to 27.8% of college graduates (Ogden et al., 2017). Additionally, Hajian-Tilaki et al. (2010) reported a negative association between obesity and the level of education.

Similar issues were found when we studied the association between obesity and countries. We could not draw definitive conclusions; however, a study examining the health effects of overweight and obesity in 195 countries over 25 years showed that obesity rates have doubled in more than 70 countries and have continuously increased in most others between 1980 and 2015. Generally, the prevalence of obesity increased with the rise in the Socio-demographic Index (SDI), which combines information on a country's economy and education, across all age groups (Hay & Collaborators, 2017).

Because overweight and obesity are prevalent among various countries and education levels, it may be beneficial to employ diverse educational methods for pilgrims, especially those from developing countries or with limited education, such as high school or less. These methods could include brochures, motion graphics sent to their phones, and TV screens in waiting areas.

These findings are preliminary but provide essential insights for public health management, identifying nutritional needs and knowledge gaps among international pilgrims. Understanding these factors is crucial for efficiently allocating healthcare resources and preparing for emergencies during large-scale gatherings. Furthermore, the study's findings have the potential to enhance pilgrim satisfaction and the overall experience by informing culturally sensitive and inclusive health and nutrition strategies. By addressing these key areas, the Kingdom of Saudi Arabia can reinforce its capability and reputation in effectively managing significant global religious events, ultimately promoting the well-being of pilgrims, and ensuring a safer, more fulfilling pilgrimage experience.

Additionally, in light of the study findings indicating low nutritional knowledge, we should consider this when planning diets for a diverse group of pilgrims and Umrah visitors. This process involves taking into account various dietary preferences, restrictions, and cultural backgrounds. To address both the quality and quantity of food provided, we recommend the following: offering a varied menu that includes vegetarian, vegan, gluten-free, dairy-free, and culturally diverse dishes, all clearly labeled for allergens and ingredients. Customizable meal stations with healthy options cater to individual preferences, which is especially important for those with chronic health conditions. Offering smaller serving sizes allows guests to sample a range of dishes, helping to reduce food waste. Additionally, providing a mix of hot and cold dishes ensures a satisfying and inclusive dining experience for everyone.

**The study's limitations** include a small and unevenly distributed sample size across different groups. Additionally, we relied only on BMI for nutritional assessment, due to challenges in securing a private area that prevented more comprehensive measurements. Furthermore, we omitted some questions in the NK survey that related to dishes potentially unfamiliar to certain cultures.

## 5. Conclusions

It is difficult to arrive at any conclusions with regard to sample size. Ideally, these findings should be implemented in a variety and represented sample size of pilgrims and Umrah visitors. The results of the current study could be a framework for exploring the optimal nutritional education and awareness for Hajj pilgrims and Umrah visitors in Makkah, thus improving NK and NS and reducing the prevalence of the disease in these populations accordingly. Also, it might be a springboard for improving health, nutrition, and food services in Makkah.

## 6. Recommendations

Further studies should be planned with a wider scope, including an examination of their ability to adhere to their prescribed diets. Additionally, implementing a nutritional education program would be helpful to minimize health problems. The following recommendations aim to support obese & overweight pilgrims & Umrah performers with the knowledge and tools to make healthier dietary choices. It's crucial to tailor interventions to each individual's specific needs and preferences to enhance success adherence.

**1- Educational Resources:** Provide simple, easy-to-understand educational materials on nutritional knowledge for pilgrims and Umrah performers. This could include pamphlets, brochures, or online resources. Display the basic and crucial nutrition information on digital signage screens at the airport, airline, and all transportation including trains, and buses around the two Holy mosques.

**2- Individual Nutrition Counseling:** Offer personalized nutrition counseling sessions with a registered dietitian or nutritionist for a comprehensive assessment that accommodates pilgrims' and Umrah performers' dietary habits, nutrition requirements, preferences, and specific needs.

**3- Meal Planning Assistance:** Assistance in creating balanced, functional food rich, and nutrient-dense meal plans that meet the dietary requirements of each individual. Emphasize portion control and recommended daily intake (RDA) of food groups. Additionally, educate them on how to customize their meals by ensuring nutritious options are available to cater to individual dietary needs and preferences.

**4- Nutrition Workshops:** Focus on fundamental nutrition concepts, such as portion sizes, food labels, and the importance of a balanced diet.

## References

- Adriaanse, M. A., Vinkers, C. D., De Ridder, D. T., Hox, J. J., & De Wit, J. B. (2011). Do implementation intentions help to eat a healthy diet? A systematic review and meta-analysis of the empirical evidence. *Appetite*, 56(1), 183–193.
- Aguirre, F., Brown, A., Cho, N. H., Dahlquist, G., Dodd, S., Dunning, T., Hirst, M., Hwang, C., Magliano, D., & Patterson, C. (2013). IDF diabetes atlas. <https://research.sahmri.org.au/en/publications/idf-diabetes-atlas-sixth-edition>
- Alkhairi, H. A., Almatrafi, A. A., Alsulami, A. A., Alsafrani, M. A., Albogami, F. S., Almuqati, M. M., & Almatrafi, K. A. (2019). Impact of heavy physical activity and musculoskeletal pain during Umrah on the health of the Algerian population. *International Journal of Medicine in Developing Country*. <http://ijmdc.com/fulltext/51-1548705400.pdf>
- Alkhalidy, A., Alshehri, B., Albalawi, N., Alsaady, F., Alfarshooti, R., Jamal, W., Altaf, A., & Maghrabi, A. A. (2019). General and Postbariatric Nutritional Knowledge among Patients Undergoing Bariatric Surgery. *Journal of Nutrition and Metabolism*, 2019, e6549476. <https://doi.org/10.1155/2019/6549476>
- Alshehri, M. A., Alzaidi, J., Alasmari, S., Alfaqeh, A., Arif, M., Alotaiby, S. F., & Alzahrani, H. (2021). The Prevalence and Factors Associated with Musculoskeletal Pain Among Pilgrims During the Hajj. *Journal of Pain Research*, Volume 14, 369–380. <https://doi.org/10.2147/JPR.S293338>
- Alzeer, A. H. (2009). Respiratory tract infection during Hajj. *Annals of Thoracic Medicine*, 4(2), 50.
- Bany-yasin, H., Elmor, A. A., Ebrahim, B. K., Ahmed, A. A. M., Alarachi, M. R., Abedalqader, L., Amer, R., Alyousef, A. M. S., Alhajeh, Y. F., Alyoussef, A., Eid, H. A. M. A., Elsayed, M. M., Desouky, E. D. E., Salem, H. K., & Salem, M. R. (2023). Exploration of the nutrition knowledge among general population: Multi—national study in Arab countries. *BMC Public Health*, 23(1), 1178. <https://doi.org/10.1186/s12889-023-15791-9>
- Biswas, T., Townsend, N., Islam, M. S., Islam, M. R., Gupta, R. D., Das, S. K., & Al Mamun, A. (2019). Association between socioeconomic status and prevalence of non-communicable diseases risk factors and comorbidities in Bangladesh: Findings from a nationwide cross-sectional survey. *BMJ Open*, 9(3), e025538.
- Dickson-Spillmann, M., & Siegrist, M. (2011). Consumers' knowledge of healthy diets and its correlation with dietary behaviour: Consumers' knowledge of healthy diets. *Journal of Human Nutrition and Dietetics*, 24(1), 54–60. <https://doi.org/10.1111/j.1365-277X.2010.01124.x>
- Fontaine, K. R., Redden, D. T., Wang, C., Westfall, A. O., & Allison, D. B. (2003). Years of life lost due to obesity. *Jama*, 289(2), 187–193.
- Gaddoury, M. A., & Armenian, H. K. (2023). Epidemiology of hajj pilgrimage mortality: Analysis for potential intervention. *Journal of Infection and Public Health*. <https://www.sciencedirect.com/science/article/pii/S1876034123001776>
- Hajian-Tilaki, K. O., & Heidari, B. (2010). Association of educational level with risk of obesity and abdominal obesity in Iranian adults. *Journal of Public Health*, 32(2), 202–209.
- Hakli, G., As, E., Ucar, A., Özdoğan, Y., Yılmaz, M. V., Özçelik, A. Öz., Lu, M. S. S., Lu, F. P. Ç., & Akan, L. S. (2016). Nutritional knowledge and behavior of adults: Their relations with sociodemographic factors. *Pakistan Journal of Nutrition*, 15(6), 532.
- Hay, S., & Collaborators, G. B. of D. 2015 O. (2015). Health effects of overweight and obesity in 195 countries over 25 years. *New England Journal of Medicine*, 377. <https://ora.ox.ac.uk/objects/uuid:51a548b1-294d-4402-851d-1d90051a0211>
- Husain, W., Ashkanani, F., & Al Dwairji, M. A. (2021). Nutrition Knowledge among College of Basic Education Students in Kuwait: A Cross-Sectional Study. *Journal of Nutrition and Metabolism*, 2021, e5560714. <https://doi.org/10.1155/2021/5560714>
- Karamravan, J., Koohi, K., & Abbaszadeh, M. (2014). Nutrition knowledge and eating behavior. *Advances in Environmental Biology*, 862–868.
- Kelly, T., Yang, W., Chen, C.-S., Reynolds, K., & He, J. (2008). Global burden of obesity in 2005 and projections to 2030. *International Journal of Obesity*, 32(9), 1431–1437.

- Kliemann, N., Wardle, J., Johnson, F., & Croker, H. (2016). Reliability and validity of a revised version of the General Nutrition Knowledge Questionnaire. *European Journal of Clinical Nutrition*, 70(10), 1174–1180.
- Klohe-Lehman, D. M., Freeland-Graves, J., Anderson, E. R., McDowell, T., Clarke, K. K., Hanss-Nuss, H., Cai, G., Puri, D., & Milani, T. J. (2006). Nutrition knowledge is associated with greater weight loss in obese and overweight low-income mothers. *Journal of the American Dietetic Association*, 106(1), 65–75.
- Knight, J. A. (2011). Diseases and disorders associated with excess body weight. *Annals of Clinical & Laboratory Science*, 41(2), 107–121.
- Koch, F., Hoffmann, I., & Claupein, E. (2021). Types of nutrition knowledge, their socio-demographic determinants and their association with food consumption: Results of the NEMONIT study. *Frontiers in Nutrition*, 8, 630014.
- Marghani, O. A., Alherabi, A. Z., Herzallah, I. R., Saati, F. A., Tantawy, E. A., Alandejani, T. A., Faidah, H. S., Bawazeer, N. A., Marghalani, A. A., & Madani, T. A. (2016). Acute rhinosinusitis during Hajj season 2014: Prevalence of bacterial infection and patterns of antimicrobial susceptibility. *Travel Medicine and Infectious Disease*, 14(6), 583–587.
- Miller, L. M. S., Gibson, T. N., & Applegate, E. A. (2010). Predictors of nutrition information comprehension in adulthood. *Patient Education and Counseling*, 80(1), 107–112.
- Mo'ath, F. B., & Attlee, A. (2021). Reliability and validity of Arabic version of revised general nutrition knowledge questionnaire on university students. *Public Health Nutrition*, 24(5), 851–860.
- Mowe, M., Bosaeus, I., Rasmussen, H. H., Kondrup, J., Unosson, M., Rothenberg, E., & Irtun, Ø. (2008). Insufficient nutritional knowledge among health care workers? *Clinical Nutrition*, 27(2), 196–202.
- MUSAIGER, A. O., Al-Mannai, M., Tayyem, R., Al-Lalla, O., Ali, E. Y., Kalam, F., Benhamed, M. M., Saghir, S., Halahleh, I., & Djoudi, Z. (2012). Prevalence of overweight and obesity among adolescents in seven Arab countries: A cross-cultural study. *Journal of Obesity*, 2012. <https://www.hindawi.com/journals/job/2012/981390/abs/>
- Ogden, C. L., Fakhouri, T. H., Carroll, M. D., Hales, C. M., Fryar, C. D., Li, X., & Freedman, D. S. (2017). Prevalence of obesity among adults, by household income and education—United States, 2011–2014. *Morbidity and Mortality Weekly Report*, 66(50), 1369.
- Parmenter, K., & Wardle, J. (1999). Development of a general nutrition knowledge questionnaire for adults. *European Journal of Clinical Nutrition*, 53(4), 298–308.
- Petrie, J. R., Guzik, T. J., & Touyz, R. M. (2018). Diabetes, hypertension, and cardiovascular disease: Clinical insights and vascular mechanisms. *Canadian Journal of Cardiology*, 34(5), 575–584.
- Pi-Sunyer, X. (2009). The Medical Risks of Obesity. *Postgraduate Medicine*, 121(6), 21–33. <https://doi.org/10.3810/pgm.2009.11.2074>
- Seravalle, G., & Grassi, G. (2017). Obesity and hypertension. *Pharmacological Research*, 122, 1–7.
- Thompson, C., Vidgen, H. A., Gallegos, D., & Hannan-Jones, M. (2021). Validation of a revised general nutrition knowledge questionnaire for Australia. *Public Health Nutrition*, 24(7), 1608–1618.
- Tiptaradol, S., & Aekplakorn, W. (2012). Prevalence, awareness, treatment and control of coexistence of diabetes and hypertension in Thai population. *International Journal of Hypertension*, 2012. <https://www.hindawi.com/journals/ijht/2012/386453/>
- Turkistani, A. M. S. (2022). The Special Dietary Needs of Pilgrims and Practices of Agencies Regarding Food Quality and Safety During the Hajj. *Biosciences Biotechnology Research Asia*, 19(3), 757–766.
- Yahia, N., Wang, D., Rapley, M., & Dey, R. (2016). Assessment of weight status, dietary habits and beliefs, physical activity, and nutritional knowledge among university students. *Perspectives in Public Health*, 136(4), 231–244. <https://doi.org/10.1177/1757913915609945>

- Yezli, S. (2023). Risk factors for heat-related illnesses during the Hajj mass gathering: An expert review. *Reviews on Environmental Health*, 38(1), 33–43. <https://doi.org/10.1515/reveh-2021-0097>
- Zaborowicz, K., Czarnocinska, J., Galinski, G., Kazmierczak, P., Górski, K., & Durczewski, P. (2016). Evaluation of selected dietary behaviours of students according to gender and nutritional knowledge. *Roczniki Państwowego Zakładu Higieny*, 67(1). <https://bibliotekanauki.pl/articles/874862.pdf>







## A Healthier Hajj: Combating diseases and public health threats through preventive management.

Alaa Barhamain<sup>1\*</sup>, Mohammad Alharazi<sup>2</sup>, and Ahmed Ghulam<sup>3</sup>

1- Preventive medicine specialist, medical director, Public health and preventive medicine executive administration, Makkah Healthcare cluster, 2- Preventive medicine and public health Consultant, Executive director, public health and preventive medicine executive administration, Makkah Healthcare cluster, 3- Urology specialist, Assistant Executive Director, Strategy department, Alnoor Specialist Hospital, Makkah.

\*Corresponding author: E-mail (Alaabarhamain@gmail.com)

### حج أكثر صحة: مواجهة الأمراض ومخاطر الصحة العامة من خلال إدارة الصحة الوقائية

آلاء سامي برهمين<sup>1\*</sup>، حمد كامل الحارزي<sup>2</sup>، أحمد زكريا غلام<sup>3</sup>

1- إخصائي الطب الوقائي، المدير الطبي بالإدارة التنفيذية للصحة العامة والطب الوقائي، تجمع مكة المكرمة الصحي، 2- استشاري الطب الوقائي والصحة العامة، المدير التنفيذي بالإدارة التنفيذية للصحة العامة والطب الوقائي، تجمع مكة المكرمة الصحي، 3- خصائي جراحة المسالك البولية، مساعد المدير التنفيذي للإدارة الاستراتيجية بمستشفى النور التخصصي، مكة المكرمة.

#### الملخص

تسلط هذه الدراسة الضوء على آلية تفعيل الإجراءات الوقائية لإدارة مخاطر الصحة العامة خلال موسم حج ١٤٤٤ للهجرة في مكة المكرمة، وتتناول على وجه التحديد مجال الوقاية من مخاطر تفشي الأمراض المعدية والوقاية من إصابات وخز الإبر لدى الممارسين الصحيين خلال موسم الحج 1444 هـ، حيث نشهد تزايد مخاطر الصحة العامة مؤخراً لاسيما فيما يختص بالأمراض المعدية الجديدة والمنبثقة، وتهتم السلطات الصحية السعودية على مر الأعوام بتقديم الخدمات والتدابير الوقائية التي تضمن سلامة الحجاج والمواطنين والعاملين في مجال الرعاية الصحية وتشمل هذه الإجراءات التطعيمات الإلزامية قبل موسم الحج، ووضع خطط التقصي والاستجابة السريعة وتنفيذ البروتوكولات الوقائية، واستعمال أحدث وسائل التقصي والمراقبة الإلكترونية، هذا بالإضافة إلى إجراءات مراقبة الصحة البيئية من سلامة الماء والغذاء وجهود مكافحة ومراقبة نواقل المرض، وترقية البنية التحتية في المنشآت الصحية بمكة المكرمة والمشاعر المقدسة، وإقامة ورش عمل وحملات توعوية للحجاج والعاملين في مجال الرعاية الصحية. وقد أثبتت هذه الإجراءات فعاليتها في تقليل نسبة انتشار الأمراض المعدية خلال موسم الحج مما يعد مثلاً عملياً في إعطاء الأولوية لسلامة والصحة العامة حتى في أكثر الظروف صعوبة وتجربة قيمة في مجال الإدارة الفعالة للمخاطر الصحية أثناء موسم الحشود في جميع أنحاء العالم.

الكلمات الدالة: الحج، الصحة العامة، الأمراض المعدية، الإجراءات الوقائية، بروتوكولات إجرائية، إصابات وخز الإبر، طب الحشود.

#### Abstract

This research focuses on the implementation of operational protocols for preventive management during the annual Hajj season in Makkah, specifically addressing communicable disease outbreaks and needlestick injury prevention among healthcare workers during Hajj season 1444 H. With a backdrop of increasing public health risks associated with

emerging diseases, Saudi health authorities proactively designed and executed measures to ensure the safety of pilgrims, citizens, and healthcare workers. The preventive management framework for Hajj 1444 included mandatory pre-travel vaccinations, comprehensive operational protocols, early detection and rapid response flowcharts, electronic surveillance technology, environmental safety measures, vector control efforts, infrastructure upgrades, enhancement of monitoring and reporting systems, and educational campaigns for both pilgrims and healthcare workers. These interventions effectively decreased the incidence of communicable diseases during Hajj, showcasing the efficacy of proactive approaches. This Paper highlights the practicality of prioritizing safety and well-being in challenging circumstances, offering valuable insights into the effective management of health risks during mass gatherings worldwide.

**Keywords:** Hajj, Public health, Communicable diseases, Preventive measures, Operational protocol, Needlestick injury, Mass gathering.

### 1. Introduction

In the holy city of Makkah, the annual Hajj pilgrimage is a mass gathering like no other, drawing over 2 million pilgrims from 184 countries from all corners of the globe [1]. Hajj poses a significant risk for the outbreak and spread of communicable diseases due to the inevitable overcrowding during the pilgrims' stay, greatly increasing the risk of acquiring and spreading infectious diseases, especially respiratory diseases [2]. Continuous monitoring of emerging infectious diseases is crucial to prevent transmission to other pilgrims and avoid a worldwide epidemic [3]. The Saudi Ministry of Health has strengthened recommendations based on available data to combat these health risks [4]. With the potential for communicable diseases to spread rapidly in such an environment [5,6], the successful implementation of operational protocols and clinical pathways for the preventive management of highly important communicable diseases became a beacon of hope for public health safety and mass gathering medicine.

### 2. The Challenge:

Hajj season poses a significant risk for the outbreak and spread of communicable diseases [2]. With millions of pilgrims in proximity, diseases such as respiratory infections, gastroenteritis, and meningitis could quickly reach epidemic proportions. In addition, healthcare workers attending to the pilgrims during Hajj season are at an increased risk of needlestick injuries, which pose a potential threat of transmitting serious infections including hepatitis B, hepatitis C, and HIV [3]. This was a significant concern for both the healthcare workers and the pilgrims they served.

Saudi Arabia has extensive experience in providing health care at mass gatherings acquired through decades of managing millions of pilgrims at the Hajj. Throughout history, Saudi health authorities' efforts to combat these health risks were never short. The Saudi Ministry of Health has strengthened recommendations based on available data to combat these health risks [4]. As public health risks have only increased in the last decade due to emerging and reemerging communicable diseases, it was necessary to face these challenges with clear prevention and mitigation plans and implement clear clinical pathways that ensure the safety and security of pilgrims, citizens, and healthcare workers.

### 3. Implementing preventive management against communicable diseases:

In the heart of Makkah, a robust framework for preventive management of communicable diseases took place during Hajj. The success of risk mitigation plans during Hajj 2020, amidst the COVID-19 pandemic, demonstrates the importance of proactive measures to prevent associated outbreaks [7]. It was essential to continuously monitor and strengthen prevention and mitigation plans to ensure the safety and security of pilgrims, citizens, and healthcare workers.

These efforts continue to serve as a model for managing health and safety during mass gatherings, safeguarding not only the pilgrims but also global public health. The successful implementation of preventive health measures significantly reduced the number of communicable diseases during the Hajj season. Rapid response teams were able to contain outbreaks swiftly. Fewer pilgrims returned home with infections, reducing the risk of international transmission, which is a cornerstone of mass gathering medicine. The Saudi Government has a well-established framework overseeing the planning, communication, security, health, safety, and administrative aspects of Hajj.

In their study on infectious disease surveillance and control during Hajj [3], Memish et al. highlighted the challenges associated with this mass gathering, emphasizing the need for vigilance and preventive measures. The public health measures for the Hajj prioritize ensuring safe water and food supplies, sanitation, vector control, compliance with pre-travel health regulations, guidance on vaccinations, health assessments, and specific immunizations at entry ports. Health education campaigns are conducted before, during, and after the season, and free healthcare services are provided to pilgrims through various, easily accessible clinics and hospitals. A proactive public health program is launched before each Hajj, emphasizing the prevention and surveillance of health hazards, along with the provision of healthcare during Hajj.

**a. Pre-travel Vaccination and chemoprophylaxis:** Mandatory vaccinations were introduced for specific diseases on arrival, ensuring that all incoming pilgrims were immunized and given the appropriate immuno-chemoprophylaxis [4]. This not only protected them but also reduced the risk of disease transmission. The Hajj and Umrah vaccine requirements include mandatory vaccinations against COVID-19 with the approved vaccines in the Kingdom, yellow fever, quadrivalent meningococcal polysaccharide (every 3 years) or conjugated (every 5 years) vaccines, and poliomyelitis vaccine. Influenza vaccine was recommended but was not obligatory for pilgrims. Ciprofloxacin is required for individuals >12 years excluding pregnant women as chemoprophylaxis to be given at the port of entry for Pilgrims coming from the meningitis belt. With the ongoing outbreaks of measles in Europe, it is recommended that all pilgrims have an updated immunization against vaccine-preventable diseases (Diphtheria, Tetanus, Pertussis, Polio, Measles, and Mumps).

**b. Operational Protocols for preventive management of communicable diseases:** A comprehensive set of operational protocols was developed by the executive administration of public health and preventive medicine at Makkah healthcare cluster, focusing on early detection, rapid response, and prevention of highly important communicable diseases during the Hajj season provided by the Saudi Ministry of Health annually before Hajj season.

Table 1: Highly Important communicable diseases during Hajj 1444 H

Meningococcal Meningitis
Other Meningitis
Covid 19
Seasonal Influenza
MERS-CoV
Mpox (Previously, Monkey pox)
Dengue fever
Hemorrhagic fever (Ebola/ Marburg)
Other hemorrhagic fever (e.g.: Yellow fever)
Acute flaccid paralysis (Polio)
Acute watery diarrhea (Cholera)
Food-borne diseases
Malaria

These protocols were designed to be accessible and intuitive for healthcare professionals in different fields, aligned with the most recent recommendations and guidelines provided by the Saudi Public Health Authority (Weqaya) and Ministry of Health (MOH).

The main objective was to promote evidence-based practice and to ensure a comprehensive, timely, and effective preventive management approach when dealing with suspected infectious diseases to prevent and control transmission among pilgrims, community members, other patients, and healthcare workers.

The comprehensive, single-page flowchart for each disease was structured to facilitate easy dissemination and retrieval of information.

More details, assigned responsibilities, relevant information, and documents were shared among stakeholders and end-users (healthcare workers) through email correspondence ensuring swift and direct communication.

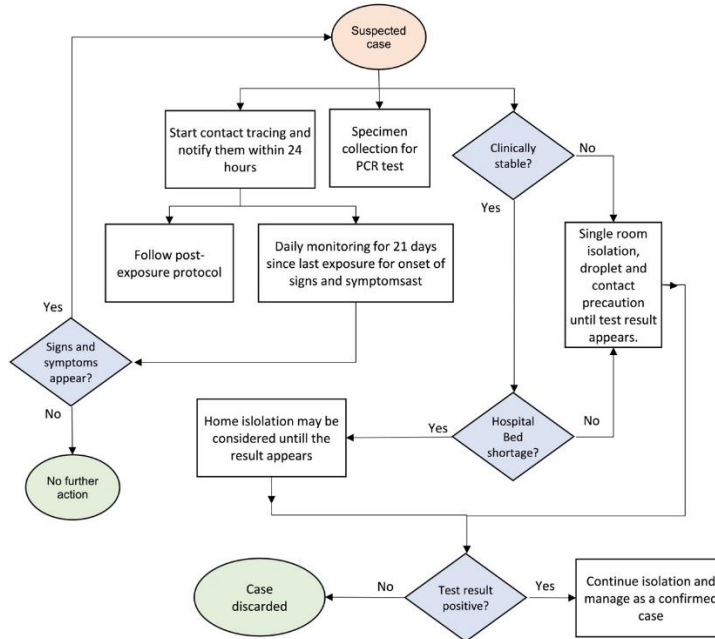
While email was the main means of knowledge sharing, it is important to note that other channels have been used in conjunction for a more comprehensive approach to knowledge dissemination, including shared drives, training sessions, workshops, and webinars targeting stakeholders.

Operational protocol for Mpox preventive management

Contact definition:

A person who, in the period beginning with the onset of the source case's first symptoms, and ending when all scabs have fallen off, has had one or more of the following exposures with a probable or confirmed case of monkeypox:

- Face-to-face exposure (including health care workers without respiratory protection)
- Direct physical contact, including sexual contact
- Contact with contaminated materials such as clothing or bedding



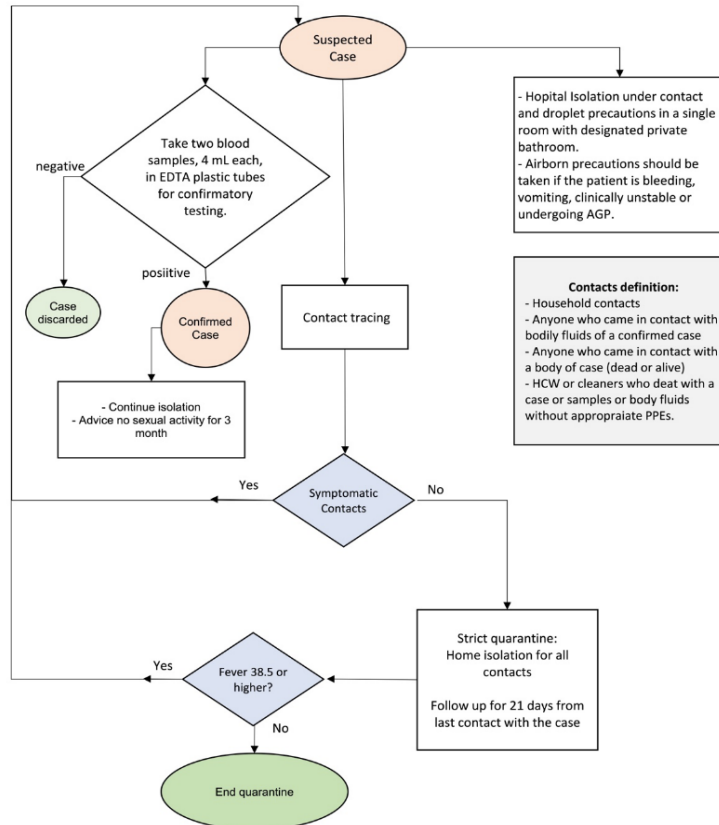
Post exposure prophylaxis (vaccination):

To be given ASAP within 4 days for:

- General population: in case of high risk exposure to a confirmed case.
- Healthcare workers: in case of high risk unprotected exposure to a confirmed or a probable case.

Flowchart 1: Operational Protocol for preventive management of Mpox suspected case

Operational protocol for preventive management of Ebola cases and close contacts

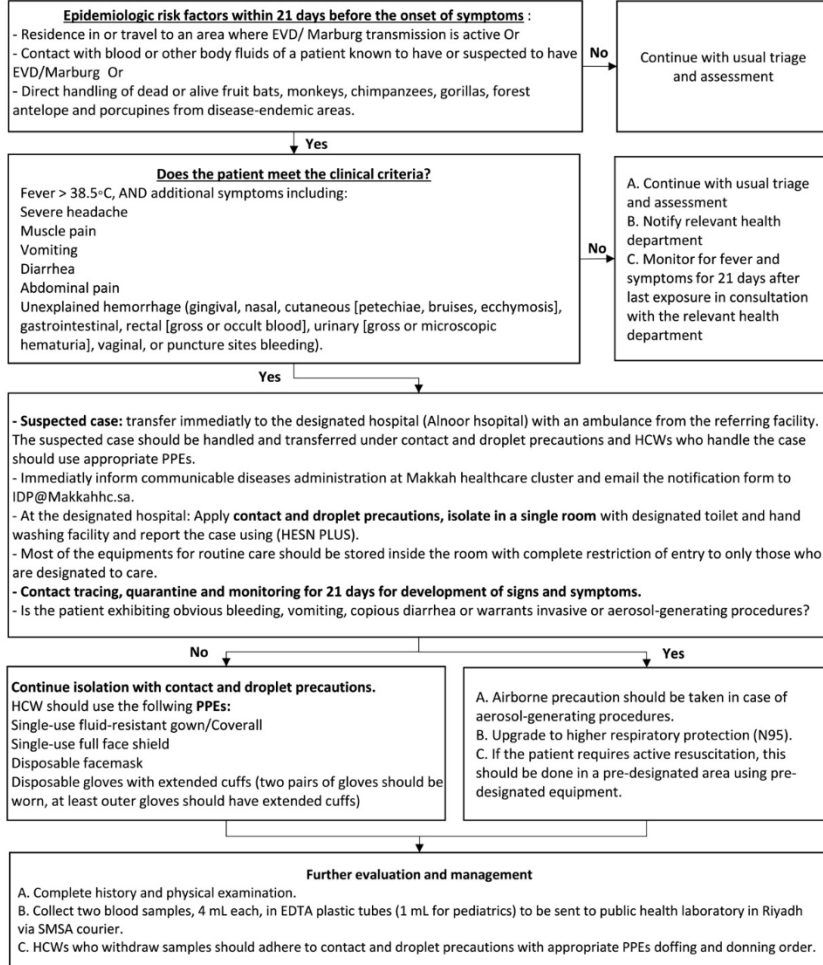


Flowchart 2: Operational Protocol for preventive management of suspected Ebola/ Marburg cases

The successful implementation of these protocols was a well-coordinated effort that demanded thorough planning and collaboration across diverse fields. The interdisciplinary nature of the collaboration drew on expertise in various critical domains, including preventive medicine, disease epidemiology, public health emergency response, infectious disease prevention and control guidelines, risk communication, training, technology, logistic resolutions, and regulatory compliance (Flowchart 3).

A key aspect of the implementation involved the establishment of both specialized fixed and mobile rapid-response medical teams. These teams were strategically positioned to respond promptly to potential outbreaks. Additionally, dedicated quarantine facilities were set up to effectively manage and isolate individuals displaying symptoms of communicable diseases. These facilities were strategically placed around pilgrims' residence locations, Almashaer hospitals, and primary care centers. This strategic positioning was deliberate, aiming to guarantee not only the availability of facilities but also easy accessibility for those in need.

## Operational protocol for Ebola and Marburg viral diseases suspected cases in Emergency Departments



Flowchart 3: Operational protocol for Ebola/ Marburg suspected cases in Emergency Departments

To support these measures, there was a strong emphasis on providing easy access to essential resources. This included ensuring the availability and accessibility of diagnostic tools, preventative measures, protective gear, and therapeutic equipment. Adequate manpower and infrastructure were also carefully considered to ensure the protocols could be executed seamlessly. This comprehensive approach aimed to curtail the spread of infections and protect the larger population.

**c. Enhanced Surveillance:** The use of electronic surveillance technology during Hajj plays a crucial role in monitoring and managing the health status of pilgrims [8]. Electronic surveillance allows for continuous tracking of pilgrims from the moment they enter the country and throughout their stay in the holy city of Makkah. This technological approach significantly enhances the ability to detect health issues early, enabling rapid response and the application of preventive measures to suspected cases and their contacts without delay. Preventive measures include early case identification, contact tracing, real-time monitoring, isolation and quarantine, immunization and chemoprophylaxis, health education,

and effective communication. All communicable diseases during mass gatherings were under surveillance, most importantly COVID-19, Seasonal Influenza, MERS-CoV, Mpox, Dengue fever, Malaria, Measles, Food poisoning, Cholera, Meningitis, Viral hemorrhagic fevers such as Ebola and Marburg, as well as yellow fever, Polio, and Plague.

**d. Environmental safety and vector control efforts:** The inaugural recorded outbreak during Hajj dates back to 632 A.D., identifying Malaria as the initial culprit and terming it "Yathrib fever" [9]. Recognition of the potential public health consequences prompted the Saudi Government to direct its efforts toward implementing specific prevention and control programs during the Hajj season. Environmental safety and vector control efforts are of paramount importance to ensure the well-being of pilgrims and the local population. Vector control efforts, such as the use of long-lasting insect repellents before Hajj season at pilgrims' locations, play a crucial role in preventing the transmission of diseases like Malaria and Dengue fever.

Comprehensive waste management and sanitation practices are implemented to prevent environmental contamination and the attraction of disease-carrying vectors. This includes the proper disposal of waste, testing water samples and maintaining clean water sources, health inspection for kitchens and food handlers, and ensuring that regular sanitation measures are taking place.

Throughout the year, inspections cover all main water supply sources and water tanks in diverse locations such as schools, government departments, residences, mosques, hotels, and food stores in Makkah. Rigorous surveys are conducted among kitchen staff at hotels and hospitals to identify potential carriers of gastrointestinal pathogens and to uphold food hygiene standards. Inspections are routinely conducted in kitchens, and samples of both food and water are scrutinized to ensure adherence to health regulations. Additionally, swabs are taken from utensils, throats, and nails of kitchen workers to test for the presence of pathogens. To prevent potential health risks, the Ministry of Health strictly enforces regulations prohibiting pilgrims from bringing fresh food or agricultural products into Saudi Arabia.

**e. Education and Awareness:** Pilgrims were provided with extensive education on preventive measures against health threats. This included hygiene practices, vaccination requirements, and disease prevention measures. Health education classes and campaigns in multiple languages were delivered to pilgrims at their locations to ensure they understood the importance of preventive health measures.

Consideration is given to the diverse cultural, ethnic, and linguistic backgrounds of pilgrims in the educational and health awareness campaigns designed to prevent public threats during Hajj. Appropriate educational materials are created and distributed through collaboration with relevant stakeholders, such as travel agents, and tour organizers in the pilgrims' countries of origin. These materials encompass information about vaccination requirements and precautions to be observed before and during the Hajj. Various health educational resources, including guides, pocket cards, stickers, leaflets, and posters, are distributed to all sites in Makkah. These materials are available in multiple languages, including English, Arabic, Urdu, and others, and incorporate images and sign language.

#### 4. Needlestick Injury Prevention During Hajj Season 1444 H

Protecting the healthcare workers who served millions of pilgrims who came to the holy city had always been a priority. Before the implementation of comprehensive safety measures, healthcare workers attending to the pilgrims during Hajj season were at an increased risk of needlestick injuries, which posed a potential threat of contracting serious infections including Hepatitis B, Hepatitis C, and HIV. Accidental needlestick injuries are a common occupational hazard in healthcare settings, with a prevalence ranging from 13.2% to 63.6% among healthcare workers [10]. Studies have shown



that healthcare workers, including those in tertiary hospitals, may not be fully aware of good injection safety practices, with over 75% reported to lack awareness [11].

The limited awareness coupled with inadequate reporting of occupational incidents, particularly during the bustling days of Hajj, increases the likelihood of needlestick injuries and the potential transmission of bloodborne pathogens without reporting such an incident. Therefore, it was crucial to address this occupational hazard and improve safety and surveillance measures to protect healthcare workers during Hajj.

A multi-faceted approach took place during Hajj 1444H that included raising awareness, educating healthcare workers, enhancing surveillance and reporting of occupational injuries, and implementing an operational protocol for preventive management of needle stick injuries at Almashaer hospitals and primary healthcare centers (PHCs) with practical solutions to conquer logistic and operational challenges, especially during Hajj peak days.

**a. Awareness and Education:** The first step was to establish widespread awareness about the risks associated with needlestick injuries. Seminars, workshops, and training sessions were organized to educate healthcare workers who are participating in Hajj season about safe needle handling practices, the importance of personal protective equipment (PPE), and the steps to follow in case of injury as per the operational protocol developed by the executive administration of public health and preventive medicine at Makkah healthcare cluster.

**b. Improved preparedness and Infrastructure:** Recognizing the unique demands of Hajj season, primary healthcare centers and other healthcare institutions located at Almashaer underwent infrastructure upgrades. To enhance safety, strategically positioned sharps disposal containers were installed, promoting the proper disposal of needles and sharp objects. In anticipation of potential incidents, each hospital and Primary Healthcare Center (PHC) at Almashaer compiled and provided essential resources, including blood tubes for serological testing, along with post-exposure prophylactic medications, vaccines, and immunoglobulins against HIV and Hepatitis B. These crucial supplies, mandated for administration within a 72-hour window for optimal effectiveness, were made readily available to ensure quick and efficient access during the peak days of the Hajj pilgrimage.

In addition to the aforementioned measures, logistical challenges associated with transferring blood samples were proactively addressed during the planning phase. A collaborative arrangement was established with a logistic company to ensure the swift and secure handling and transportation of blood samples to the regional lab in Makkah City.

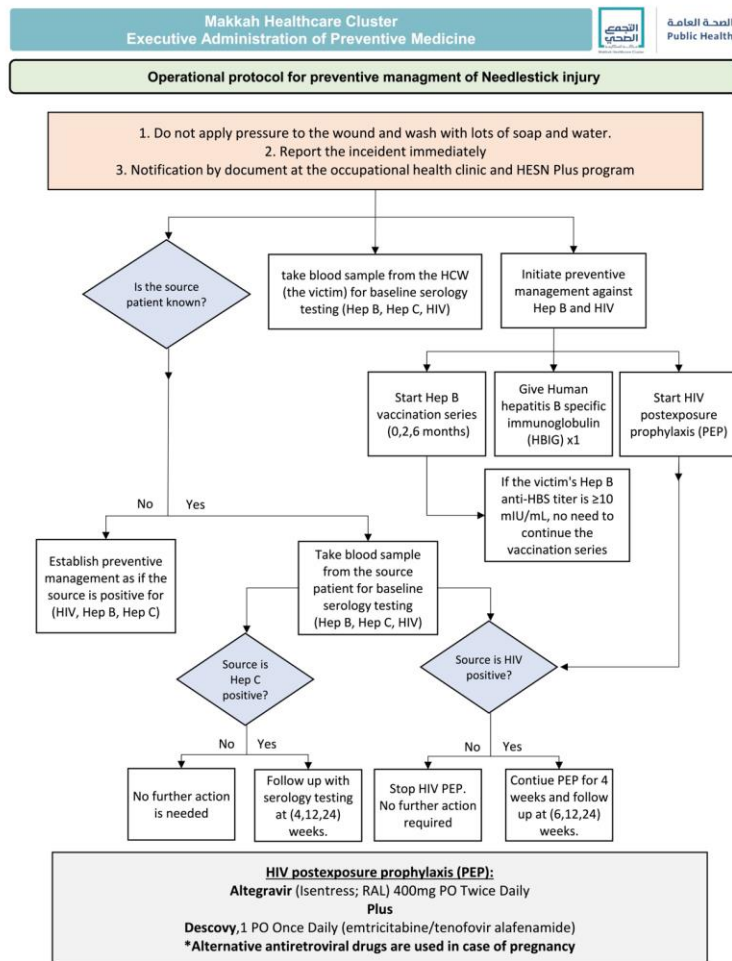
**c. Surveillance, monitoring, and reporting:** A clear system for monitoring and reporting needlestick injuries was established. Healthcare workers were encouraged to report such incidents promptly through clear communication channels, which enabled rapid response and initiation of preventive management.

**d. The operational protocol for preventive management of needlestick injuries during hajj season:** In response to the heightened risk of needlestick injuries among healthcare workers during the Hajj season, an operational protocol has been meticulously formulated to establish a clear and comprehensive pathway for the management of such incidents (Flowchart 4). This protocol outlines a step-by-step approach, providing immediate actions, reporting procedures, and subsequent steps for both scenarios where the source patient is known and instances where the source patient's identity is unknown. Special attention is given to cases with unknown source patients, with guidelines for initiating blood investigations to identify the serological status of the source regarding Hepatitis B, Hepatitis C, and HIV in order to take measures to prevent potential transmission of bloodborne pathogens.

The protocol mandates necessary baseline blood serology tests to assess potential exposure, and in cases of suspected exposure to bloodborne pathogens, vaccination, and administration of prophylactic treatment against Hepatitis B and

HIV are promptly initiated within 72 hours. Follow-up appointments are scheduled over a period of six months to monitor and assess healthcare workers who have experienced needlestick injuries while handling a source patient who is positive for bloodborne pathogens.

Rigorous documentation and reporting mechanisms, coupled with training and education programs, ensure healthcare professionals are well-versed in the established procedures, fostering a culture of awareness and preparedness. This evolving and adaptive protocol prioritizes the health and safety of individuals affected by needlestick injuries during the unique and challenging circumstances of the Hajj season, contributing to a resilient and proactive healthcare framework. Understanding the cultural context of the pilgrimage and its significance, healthcare workers were trained to communicate with pilgrims effectively. This helped in ensuring the cooperation of the pilgrims to be tested for infectious diseases after such an injury and maintain safe healthcare practices.



Flowchart 4: Operational protocol for preventive management of needlestick injury among healthcare workers during Hajj season

These efforts bore fruit. Needlestick injuries among healthcare workers were successfully reported and immediate action was taken to prevent health complications. Eighteen cases of needle stick injuries were reported during Hajj season 1444 H as compared to only (2-3) reported cases in previous Hajj seasons, reflecting a more sensitive surveillance system and

improved healthcare workers' awareness and active reporting of the incidents. As preventive interventions took place rapidly, none of the healthcare workers who were injured had developed any infectious disease upon follow-up. The success was not only measured in the number of healthcare workers who prevented complications of needle stick injury, but also in the confidence and security felt by both healthcare workers and pilgrims. The combined efforts of healthcare authorities, healthcare workers, and the pilgrims themselves had transformed the landscape of healthcare safety in the holy city of Makkah.

## 5. Results:

This paper investigated the implementation and impact of operational protocols for the preventive management of communicable diseases during Hajj season 1444H at the Makkah healthcare cluster. Comprehensive protocols were established, covering early detection, rapid response, and prevention strategies for communicable diseases. Additionally, a specialized protocol addressing needlestick injuries among healthcare workers during Hajj was developed. The successful execution of these protocols involved a multidisciplinary collaboration, incorporating preventive medicine, epidemiology, emergency response, logistics, and regulatory compliance.

The development of a single-page flowchart for each communicable disease emphasized accessibility and alignment with the latest public health guidelines. The establishment of rapid response medical teams and quarantine facilities strategically positioned across pilgrim locations highlighted a proactive approach to potential outbreaks. The success in reporting needlestick injuries among healthcare workers, coupled with timely preventive interventions, underscored the effectiveness of the protocols in a unique and challenging healthcare setting.

The results carry significant implications for public health, particularly in the context of mass gatherings like Hajj. The execution of operational protocols not only prevented the spread of communicable diseases among pilgrims and the community but also ensured the safety of healthcare workers. The emphasis on training, communication, and cultural sensitivity demonstrated a holistic approach to healthcare safety during the Hajj.

## 6. Discussion:

The contextual significance of this study lies in the unique challenges posed by the Hajj pilgrimage, where millions of individuals from diverse regions and backgrounds converge, creating an environment conducive to the rapid spread of communicable diseases. The proactive measures implemented through operational protocols reflect the adaptability and responsiveness of the healthcare system to the complex and dynamic conditions of Hajj.

The study's outcomes have broader implications for public health strategies, particularly in the context of mass gatherings. The development of accessible and evidence-based protocols can be extrapolated to other large-scale events, ensuring a timely and effective response to potential health threats.

The meticulous formulation and implementation of a protocol specifically addressing needlestick injuries among healthcare workers during Hajj signify a proactive approach to occupational safety. The success in preventing complications and infections among healthcare workers underscores the importance of tailored protocols for high-risk scenarios.

Limitations: While the protocols showcased success in preventing and managing communicable diseases and needlestick injuries during Hajj, the specific context of the pilgrimage may limit the generalizability of the results to other mass gathering settings. Comparative analyses across different mass gathering events and healthcare settings can provide insights into the generalizability of preventive measures. This study did not delve into potential challenges faced during

the implementation phase, and addressing these challenges could further enhance the adaptability of the protocols in different settings. Additionally, as clinical practice guidelines and infection control recommendations change continuously, the long-term sustainability and scalability of the protocols warrant careful consideration.

Building upon these findings, continuous information updates, ongoing training and educational programs for healthcare workers, and further studies can assess the sustained effectiveness of the protocols over multiple Hajj seasons and evaluate potential refinements based on evolving healthcare needs. Moreover, exploring the economic implications and cost-effectiveness of such proactive health measures can inform resource allocation and policy decisions.

## 7. Conclusion:

Public health measures outlined in this paper underscore the positive outcomes achievable through collaboration, education, and innovation, even in challenging settings. The efforts dedicated to safeguarding pilgrims' health and supporting healthcare workers extended beyond medical considerations to become a moral imperative during Hajj. The effective prevention of communicable diseases serves as a practical example for public health services during mass gatherings globally, demonstrating that, even in demanding circumstances, safety and well-being can be appropriately prioritized and maintained.

## References:

- 1- Metanat, M., Sharifi-Mood, B., Sanei-Moghaddam, S., & Rad, N. S. (2015). The pharyngeal carriage rate of *Neisseria meningitidis* before and after the hajj pilgrimage, in Zahedan (southeastern Iran), 2012. *Turkish Journal of Medical Sciences*, 45, 1317-1320. <https://doi.org/10.3906/sag-1405-7>
- 2- Benkouiten, S., Al-Tawfiq, J., Memish, Z., & Albarrak, A. (2019). Clinical respiratory infections and pneumonia during the hajj pilgrimage: a systematic review. *Travel Medicine and Infectious Disease*, 28, 15-26. <https://doi.org/10.1016/j.tmaid.2018.12.002>
- 3- Memish, Z., Zumla, A., Alhakeem, R., Assiri, A., Turkestani, A., Harby, K., ... & Al-Tawfiq, J. (2014). Hajj: infectious disease surveillance and control. *The Lancet*, 383(9934), 2073-2082. [https://doi.org/10.1016/s0140-6736\(14\)60381-0](https://doi.org/10.1016/s0140-6736(14)60381-0)
- 4- Al-Tawfiq, J., Zumla, A., & Memish, Z. (2014). Travel implications of emerging coronaviruses: sars and mers-cov. *Travel Medicine and Infectious Disease*, 12(5), 422-428. <https://doi.org/10.1016/j.tmaid.2014.06.007>
- 5- Moattari, A., Moghadami, M., & Honarvar, B. (2012). Influenza viral infections among the Iranian hajj pilgrims returning to Shiraz, Fars province, Iran. *Influenza and Other Respiratory Viruses*, 6(6). <https://doi.org/10.1111/j.1750-2659.2012.00380.x>
- 6- Shafi, S., Booy, R., Haworth, E., Rashid, H., & Memish, Z. (2008). Hajj: health lessons for mass gatherings. *Journal of Infection and Public Health*, 1(1), 27-32. <https://doi.org/10.1016/j.jiph.2008.08.008>
- 7- Jokhdar, H., Khan, A., Asiri, S., Motair, W., Assiri, A., & Alabdulaali, M. (2021). COVID-19 mitigation plans during hajj 2020: a success story of zero cases. *Health Security*, 19(2), 133-139. <https://doi.org/10.1089/hs.2020.0144>
- 8- Al-Tawfiq JA, Memish ZA. The Hajj 2019 Vaccine Requirements and Possible New Challenges. *J Epidemiol Glob Health*. 2019 Sep;9(3):147-152. doi: 10.2991/jegh.k.190705.001. PMID: 31529930; PMCID: PMC7310822.
- 9- Farid MA. The pilgrimage and its implications in a regional malaria eradication program. WHO/EMRO inter-regional conference on malaria for the Eastern Mediterranean and European regions. April 1956. World Health Organization Report WHO/MAL/168
- 10- Yazie, T., Chufa, K., & Tebeje, M. (2019). Prevalence of needlestick injury among healthcare workers in Ethiopia: a systematic review and meta-analysis. *Environmental Health and Preventive Medicine*, 24(1). <https://doi.org/10.1186/s12199-019-0807-7>
- 11- Mitra, M., Basu, M., & Sarker, G. (2020). Needle stick injuries in a tertiary care hospital in Bihar - current Indian scenario. *Journal of Evolution of Medical and Dental Sciences*, 9(05), 289-294. <https://doi.org/10.14260/jemds/2020/65>.

الملتقى العلمي الثالث والعشرون  
لأبحاث الحج والعمرة والزياره  
التميز الصحي في خدمة ضيوف الرحمن



جامعة أم القرى  
معهد خادم الحرمين الشريفين  
للأبحاث الحج والعمرة

## Theme of Technology Transformations in Healthcare for Pilgrims



## Clinical training and practice of using digital health solutions among healthcare workers in clinical centers during Hajj mission

Saeed Mardy Al Obaid Alghamdi

Clinical Technology Department, Respiratory Care Program, Faculty of Applied Medical Science

\*Corresponding author: E-mail (smghamdi@uqu.edu.sa)

## واقع الممارسات السريرية الصحية المتعلقة بالحلول الصحية الرقمية لدى الممارسين الصحيين المشاركين في خدمة ضيوف الرحمن

سعيد بن مرضي آل عبيد الغامدي

التقنية السريرية , برنامج الرعاية التنفسية , كلية العلوم الطبية التطبيقية.

### الملخص

مع توسع استخدام حلول الصحة الرقمية في المملكة العربية السعودية تهدف هذه الدراسة المسحية لتقييم قابلية الاستخدام أو المعوقات تجاه تطبيقات الصحة الرقمية من وجهة نظر الممارسين الصحيين المشاركين في برنامج القوى العاملة الصحية الزائرة في خدمة ضيوف الرحمن. هدفت هذه الدراسة للتعرف على مستوى الوعي وواقع وعوائق استخدام تقنيات الصحة الرقمية أثناء مهمة الحج من وجهة نظر الممارسين الصحيين المشاركين في برنامج القوى العاملة الصحية الزائرة في الحج. تكونت عينة هذه الدراسة من (470) مشاركا وشملت (13) تخصصا طبييا مختلفا. أشارت نتائج الدراسة بصورة عامة أن الممارسين الصحيين المشاركين في الحج لديهم الوعي والتدريب الكافي والخبرة السريرية للعمل ضمن فرق التطبيب عن بعد. كما جدد نتائج هذه الدراسة أن (37.3%) من الممارسين الصحيين المشاركين في مهمة الحج يتمتعون بتدريب سريري جيد على إدارة الحلول الصحية الرقمية في موسم الحج. كما نوهت الدراسة على أن (37.4%) من الممارسين الصحيين يتفقون على الحاجة لمزيد من البرامج التوعوية والتدريبية حول أهمية وفاعلية الصحة الرقمية للحاج والمعتمر قبل الوصول إلى مكة لأداء الحج مما يساهم إيجابيا في رفع مستوى الوعي بأهمية وفائدة تطبيقات الصحة الرقمية في موسم الحج. أيضا يعتقد (39.4%) من الممارسين الصحيين أن حلول الصحة الرقمية مفيدة أثناء الحج لتفادي تأخر وصول المريض إلى مراكز الرعاية الصحية بسبب صعوبة التنقل. وأوصت الدراسة بأنه بالإمكان رفع كفاءة الاتصال الرقمي الصحية بحيث يساهم في تحسين جودة التطبيب عن بعد والوصول السريع للخدمات الطبية للحاج والمعتمر في سياق رفع مستوى التميز الصحي في خدمة ضيوف الرحمن. الكلمات الدالة: الصحة الرقمية، التطبيب عن بعد، حلول الصحة الرقمية، ضيوف الرحمن، التميز الصحي.

### Abstract

**Background:** Digital health (DH) solutions are widely used in Saudi Arabia, but despite this, neither the utilization nor the attitude, or challenges toward using DH applications have been evaluated from the prospective of healthcare workers (HCWs) in Hajj mission. **Aims:** This cross-sectional study aims to explore clinical training and practice, as well as challenges of DH use among HCWs who participated in Hajj mission. **Results:** 470 HCWs completed the questionnaire. Overall, there were 13 health professions involved in using DH applications in clinical settings. We found that 37.4% of the HCWs strongly agree to the statement that they would like to receive more clinical training on DH. In addition, 34.9%

of HCWs felt comfortable training colleagues on using DH within the clinical setting. In the clinical practice of using DH, 39.4 % of the HCWs strongly agree that DH is useful and beneficial during transportation difficulties, as well as 35.5% of the responders strongly agree that DH applications have changed their working routine during Hajj mission. We also found a variety of challenges reported to not using DH in clinical settings. As noted, poor internet connection reported by 174 (37.0%) as the most frequently reported challenge, followed by lack of knowledge 152 (32.3%), lack of time to use DH 149 (31.7%). Negative outcome expectations were the lowest challenges reported by the respondents 72.

**Conclusion and recommendations:** HCWs during Hajj season are confident and trained on utilizing DH solutions for pilgrims. Challenges toward using DH solutions such as poor internet connections, lack of knowledge, and lack of time have been identified. We recommended implementing more awareness campaigns about the usefulness of DH solutions during Hajj season among HCWs and pilgrims.

**Keywords:** Digital health, Telehealth, Digital health solutions, Guests of Rahman, Health excellence

### 1. Introduction

Despite the high demand for digital health (DH) services in clinical practice to facilitate care delivery, several barriers and challenges to the use of digital applications have been identified from healthcare providers' perspectives.[1, 2] Vision 2030 enhance empowering DH services to provide high level of care for residents, travelers and pilgrims.[3] Yearly, more than 1300 (90% of them were Saudis) healthcare workers are arriving to Makkah to participate in providing healthcare services for pilgrims also known as Hajj mission for healthcare providers. This is an important logistic strategy to cope with the high medical services demand during Hajj seasons. Globally, there has been a strong drive to implement and accelerate DH, led by governments and health authorities.[1, 2] Evidence continues to emerge that using DH approaches to provide and manage health services is a significant factor in stopping or controlling diseases transmission as well as reducing the pressure on healthcare systems, and facilitate controlling diseases such as COVID-19.[4] In Saudi Arabia, the Ministry Of Health (MOH) has succeeded in optimizing and maintaining a strategy to mitigate the spread of the virus during Hajj seasons via different DH technologies.[5] This strategy includes screening patients, providing daily reports about symptoms, and tracing infected cases via advanced technology, such as mobile health applications, artificial intelligence, and machine learning (Figure 1).

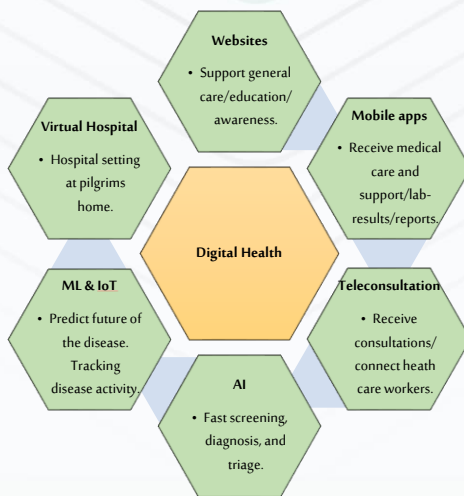


Figure 1. DH applications in during Hajj season. ML; Machine Learning, AI; Artificial Intelligence, IoT: Internet of Things.

Relatedly, the emergence of coronavirus led to a dramatic increase in the use of DH in Saudi Arabia and overwhelmed healthcare workers and DH platforms.[6] As a result, several challenges in DH services have emerged. Recently, it has been reported that physicians in still have low knowledge about DH and its use.[7] The findings of the same group also demonstrated that physicians believe that factors related to privacy, cost, and information and communication technology might limit the use of DH.[7] Moreover, Aldhahir et al, conducted a national study to evaluate perception and barriers of using digital app from public perspective.[8] The mobile health app was perceived as a reliable and easy to use. Non-users of DH reported that lack of knowledge was the most common barrier. [8]

Relatively, we previously explored DH use from both health care workers (HCWs) and population prospective using real-time data, the study demonstrated that there were more than 23 million registered users in all DH platforms in Saudi Arabia. The rate of DH use increased dramatically across four years (the report covering the period from 2019 to 2022). [6, 9] Although there has been an exponential increase in the use of DH in Saudi Arabia, the use rate of usability, as well as challenges toward using DH applications from HCWs perspective, who participated in Hajj seasons, have not been evaluated. Also, we are still inconclusive in terms of determining the professions where the DH applications were commonly feasible and applicable. Therefore, this study aims are .

1. To explore clinical training and practice of DH among HCWs who participated in Hajj mission .
2. To identify challenges of not using DH applications by HCWs during Hajj season.

## 2. Methodology (Materials and methods)

This is a cross-sectional survey was conducted during Hajj seasons 2023. The author distributed online questionnaires by Survey Monkey to collect data. The questionnaire has two domains (clinical training and practice) about DH usability. The survey was originally developed and validated by Almojaibel et al. [10, 11] Before participants started to answer the questionnaire, participants were informed about the purpose of the study, the estimated time for completing the survey, data confidentiality, and voluntary participation.

Convenience sampling techniques were implemented to recruit the study participants. All healthcare workers who involved in providing health services during Hajj seasons were the main targets of the study, no specific profession has been identified in the inclusion criteria. To ensure a countrywide sample representativeness, Hajj mission leaders were contacted to distribute the survey to registered members using their official emails. The responses of healthcare workers were summaries in Table 1.

## 3. Results and Dscussion

In this study, we approached 500 HCWs during Hajj season 2023 all of them are Saudis. Overall, 470 HCWs; 347 male (73.8%) and 123 females (26.2%), completed the online survey between July 1, 2023, and September 16, 2023. Overall, there were 13 health professions involved in using DH applications in clinical settings. Physicians accounted for 30.9%, followed by nurses (18.9%), respiratory therapists (14.9%), physiotherapists (11.7%) and other specialties such as pharmacists and radiology technicians (Table 1).

We also categorized DH utilization into less than a year, one to three, four to six, seven to nine, and more than or equal to ten years. Out of 470, 45.3% of the respondents have used DH for less than a year and 30.0% use DH from one to three years. (Table 1).



Table 1. Demographic data and characteristics of all HCWs (n= 470).

Variables	Frequency (%), Median [IQR]
Age*	40 [27 to 56]
<b>Gender</b>	Frequency (%)
Male	347 (73.8%)
Female	123 (26.2%)
<b>Year of experience (category)</b>	Frequency (%)
<1 yr.	213 (45.3%)
1 to 3 yrs.	141 (30.0%)
4 to 6 yrs.	57 (12.0%)
7 to 9 yrs.	22 (4.7%)
≥ 10 yrs.	37 (7.9%)
<1 yr.	213 (45.3%)
<b>Profession</b>	Frequency (%)
Physician	145 (30.9%)
Nurse	89 (18.9%)
Respiratory therapy	70 (14.9%)
Physiotherapy	55 (11.7%)
Pharmacy	58 (12.3%)
Radiology	13 (2.80%)
Emergency Medical Services	7 (1.50%)
Occupational therapy	5 (1.1%)
Health education	13(2.80%)
Operation room technician	2 (0.40%)
Medical Laboratory	7 (1.5%)
Biomedical Engineering	3(0.60%)
Dietitian	2(0.40%)

Data are presented as frequencies and percentages. \*Continuous variables were presented as median (IQR).

When exploring the clinical training among HCWs. We found that 31.7% and 37.4% of the HCWs agree or strongly agree to the statement that they would like to receive more training on DH. In addition, 31.30% and 34.9% of HCWs felt comfortable training colleagues on using DH within the clinical setting. (Table 2) Regarding the clinical practice of using DH, 39.4 % of the HCWs strongly agree that DH is useful and beneficial during transportation difficulties. In addition, 29.1% and 35.5% of the responders agree and strongly agree that DH applications have changed their working routine. Furthermore, 32.6% and 35.3% of the respondents agree and strongly agree that DH applications have helped to enable quick access to patient information. In clinical practice, there were 75 (16.0%) of the respondents disagree to the statement “everyone in my workplace uses DH”. (Table 2)

Table2. Clinical Training and Practice of Using DH Applications among participants (n=470)

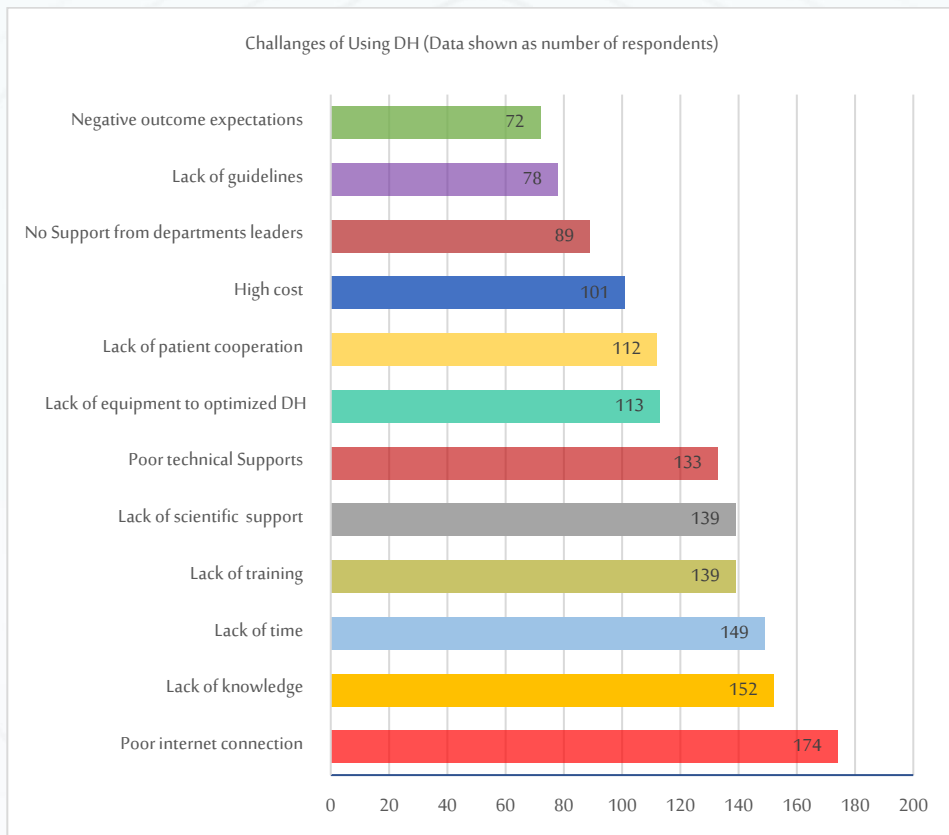
Items of Clinical Training	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
<i>I would like to receive more clinical training on DH</i>	149 (31.7%)	176(37.4%)	60(12.8%)	15 (3.27%)	2 (0.40%)
<i>I feel like I have been sufficiently trained to use DH</i>	121 (25.7%)	162 (34.5%)	77 (16.4%)	37 (7.9%)	5 (1.10%)
<i>I feel comfortable training patients on how to use DH</i>	129 (27.4%)	180 (38.3%)	63 (13.4%)	27 (5.7%)	3 (0.60%)
<i>I feel comfortable to train peers on using DH</i>	147 (31.30%)	164 (34.9%)	64(13.60%)	23 (4.90%)	4 (0.90%)
<b>Items of Clinical Practice</b>					
<i>The use of DH changed my working routine</i>	137 (29.1%)	167 (35.5%)	69 (14.7%)	25(5.3%)	4 (0.90%)
<i>DH enables me to have quicker access to information</i>	153 (32.6%)	166 (35.3%)	69 (13.8%)	16(3.4%)	2 (0.40%)

<i>Everyone in my workplace uses DH</i>	115 (24.5%)	104 (22.1%)	96 (20.4%)	75 (16.0%)	12 (2.6%)
<i>DH is useful for patients with transportation barriers</i>	158 (39.4%)	158 (33.6%)	52 (11.1%)	5 (1.1%)	2 (0.40%)
<i>Based on my experience, patients accept DH</i>	110 (23.4%)	161(34.3%)	104(22.1%)	22 (4.7%)	5 (1.1%)
<i>Based on my experience, patients like using DH</i>	100 (21.3%)	152 (32.3%)	122(26.0%)	22 (4.7%)	6 (1.3%)
<i>If I were a patient, I would like to use DH</i>	147 (31.3%)	152 (32.3%)	69 (14.7%)	28 (6%)	6 (1.3%)

Footnote: DH is digital health.

There were a variety of challenges reported to not using DH in clinical settings. As noted, poor internet connection reported by 174 (37.0%) as the most frequently reported challenge, followed by lack of knowledge 152 (32.3%), lack of time to use DH 149 (31.7%). Negative outcome expectations were the lowest challenges reported by the respondents of 72 (15.3%). (Figure 2).

Figure 1. Challenges of Using DH during Hajj Season. Data presented as number of participants.



#### 4. Conclusions

This is the first national observational study to evaluate the clinical training and practice, as well as challenges toward using DH during Hajj season among different professions. The findings of our report illustrated that the HCWs were open to use DH and received more training on using DH during Hajj season. Additionally, HCWs were cooperative in training colleagues on how to use DH. Moreover, there was a positive impact that DH is allowing fast access to the patient's information as well as with existence of transportation difficulties during Hajj mission. In addition, there were challenges

such as poor internet connections, lack of knowledge and lack of time, which influence the use of DH among HCWs during Hajj season .

This study indicated that the practice of using DH in Hajj season is improving. This perhaps due to the strategic plan by the MOH in Saudi Arabia to fully operate the DH services as alternative approach to either provide healthcare or monitoring patients during Hajj season.[6, 8, 9] At the clinical practice level, promoting DH use is a facilitator to allow and accelerate accessibility to healthcare services, especially when Hajj seasons hosted millions of people. [12] At the public health level, this is crucial as transportation in Hajj season across Makkah and Al-Mashaeer is almost limited.[13] Highlighting that our results showed that perceptions of HCWs about DH impotence and benefits in the clinical practice are promising and getting more attention compared to previous general cross-sectional surveys about DH in the Kingdom[8,2].

Our results showed, in routine clinical practice, that DH experiences made routine work proceed more quickly than usual as well as most HCWs felt adequately trained in using DH in the clinical setting, and that they felt confident using DH for their patients during Hajj season. Our result is supported by the previous studies which shown that training and confidence are important to accept and adopt DH applications in routine clinical practice. [14, 15] This a promising indicator that clinicians who participated in Hajj mission are confident and trained in using DH applications. However, not all health professions are demanding to use DH applications. During Hajj season, our report showed that physicians were the highest profession in using DH while operation room's technicians were the lowest. This might be connected to the nature of the clinical practice itself as the high demand on physician's consultations via DH, especially in Hajj seasons .[16] On the other hand, DH applications are not necessarily a favorable in clinical practice, particularly with critical patients or emergency operations where the hands on and producers are the majority of the routine workload [17] .

According to our study, poor internet connections, lack of knowledge, and lack of time were the most frequent challenges prevented HCWs from using DH during Hajj season. Clinically, this is true, since technical issues are commonly associated with low levels of utilization and satisfaction. [8, 18] Additionally, using DH applications is largely determined by the level of knowledge and skills of HCWs as well as the ease of access to DH option [19].

This study gives insights that the level of awareness about using DH during Hajj season is increasing among HCWs. Furthermore, this study provides an indication of how DH is utilized by different healthcare professions during the Hajj season. This will inform stakeholders and policymakers to activate more channels of DH solutions, which promote high-level healthcare services for pilgrims.

HCWs during Hajj season are confident and trained on utilizing DH solutions for pilgrims. In addition, DH has been perceived as beneficial for facilitating care delivery and improving patient care by HCWs. Challenges toward using DH solutions such as poor internet connections, lack of knowledge, and lack of time have been identified by HCWs whom working to provide healthcare services for pilgrims in Hajj season.

## 5. Recommendations

According to our results, the researcher recommended implementing more awareness campaigns about the usefulness of DH solutions during Hajj season among HCWs and pilgrims. By doing so, we will help to minimize workload on healthcare services and facilitate care delivery for all pilgrims who need healthcare services. Furthermore, internet companies could work in collaboration with healthcare authorities to facilitate local seasonal free-internet modems to overcome poor internet connection challenges.

## References

1. El-Mahalli, A.A., S.H. El-Khafif, and M.F. Al-Qahtani, Successes and challenges in the implementation and application of telemedicine in the eastern province of Saudi Arabia. *Perspect Health Inf Manag*, 2012. 9: p. 1-27.
2. Alghamdi, S.M., et al. Healthcare providers' perception and barriers concerning the use of telehealth applications in Saudi Arabia: A cross-sectional study. in *Healthcare*. 2022. MDPI.
3. Vision 2030. 2023 [cited 2023 14 October ]; Available from: <https://www.vision2030.gov.sa/ar/v2030/vrps/pe>.
4. Jokhdar, H., et al., COVID-19 mitigation plans during Hajj 2020: a success story of zero cases. *Health security*, 2021. 19(2): p. 133-139.
5. National E- Health Strategy. MOH Vision for "E-Health" 2023 [cited 2023; Available from: <https://www.moh.gov.sa/en/Ministry/nehs/Pages/default.aspx>.
6. Alghamdi, S.M., J.S. Alqahtani, and A.M. Aldhahir, Current status of telehealth in Saudi Arabia during COVID-19. *J Family Community Med*, 2020. 27(3): p. 208-211.
7. Albarrak, A.I., et al., Assessment of physician's knowledge, perception and willingness of telemedicine in Riyadh region, Saudi Arabia. *J Infect Public Health*, 2021. 14(1): p. 97-102.
8. Aldhahir, A.M., et al., Current Knowledge, Satisfaction, and Use of E-Health Mobile Application (Seha) Among the General Population of Saudi Arabia: A Cross-Sectional Study. *Journal of Multidisciplinary Healthcare*, 2022. 15: p. 667.
9. Alghamdi, S.M., et al. Digital Health platforms in Saudi Arabia: Determinants from the COVID-19 pandemic experience. in *Healthcare*. 2021. MDPI.
10. Almojaibel, A.A., et al., Health care practitioners' determinants of telerehabilitation acceptance. *International journal of telerehabilitation*, 2020. 12(1): p. 43.
11. Almojaibel, A.A., et al., Development and validation of the tele-pulmonary rehabilitation acceptance scale. *Respiratory Care*, 2019. 64(9): p. 1057-1064.
12. Alrufaidi, K.M., et al., Prevalence of emergency cases among pilgrims presenting at King Abdulaziz International Airport Health Care Center at Hajj Terminal, Jeddah, Saudi Arabia during Hajj Season, 1440 H—2019. *Dialogues in Health*, 2023. 2: p. 100099.
13. Al-Sabban, S.A. and H.M. Ramadan, A Simulation study of the shuttle-bus pilgrim transportation system between the Holy sites for the 1422H Hajj Season. *Engineering Sciences*, 2005. 16.(2)
14. Alsahali, S., Awareness, views, perceptions, and beliefs of pharmacy interns regarding digital health in Saudi Arabia: cross-sectional study. *JMIR Medical Education*, 2021. 7(3): p. e31149.
15. Al Baalharith, I., et al., Telehealth and Transformation of Nursing Care in Saudi Arabia: A Systematic Review. *International Journal of Telemedicine and Applications*, 2022. 2022.
16. Alshammari, S.A., Preparedness to implement "a family physician for every family," which is the magic recipe for cost-effective health care for all. *Journal of Nature and Science of Medicine*, 2023. 6(2): p. 95-100.
17. Mazur, L.M., et al., Toward a better understanding of task demands, workload, and performance during physician-computer interactions. *Journal of the American Medical Informatics Association*, 2016. 23(6): p. 1113-1120.
18. Alharbi, A., J. Alzuwaed, and H. Qasem, Evaluation of e-health (Seha) application: a cross-sectional study in Saudi Arabia. *BMC medical informatics and decision making*, 2021. 21(1): p. 1-9.
19. Al-Samarraie, H., et al., Telemedicine in Middle Eastern countries: Progress, barriers, and policy recommendations. *International journal of medical informatics*, 2020. 141: p. 104232.



## Investigating the Opportunities and Challenges of Healthcare Process Mining (HPM) in Hajj and Umrah

Amirah Alharbi

Computer Science and Artificial Intelligence department, Umm Al-Qura University

\*Corresponding author: E-mail (amnharbi@uqu.edu.sa)

### دراسة الفرص والتحديات المحتملة عند تطبيق نمذجة مسارات الرعاية الصحية المقدمة لضيوف الرحمن في مواسم الحج والعمرة

أميره محمد الحربي

قسم علوم الحاسب الآلي والذكاء الاصطناعي، جامعة أم القرى

#### الملخص

اكتسب اكتشاف ونمذجة مسارات الرعاية الصحية اهتماما في السنوات الأخيرة وأصبح ذا صلة متزايدة برقمته بيانات الرعاية الصحية. تستضيف المملكة العربية السعودية أحداثا دينية جماعية سنوية يمكن أن تشكل تحديات فريدة في مجال الرعاية الصحية بسبب العدد الكبير من الحضور واحتمال وقوع حوادث متعلقة بالصحة. يمكن أن يكون تطبيق تعدين عمليات الرعاية الصحية على التجمعات الجماهيرية أداة قيمة لإدارة خدمات الرعاية الصحية وتحسينها خلال الأحداث واسعة النطاق. هذا البحث له مساهمة جديدة في تسليط الضوء على دور تقنيات الرعاية الصحية الموجهة نحو العملية في سياق التجمع الجماهيري. يتكون العمل المقدم من جزأين رئيسيين. يحدد الجزء الأول مفهوم تعدين العمليات ويكشف فوائده من حيث نمذجة تعقيد عمليات الرعاية الصحية، وتحديد الأنماط والشذوذ في مسارات العلاج، وقياس الالتزام بالإرشادات السريرية. يقترح الجزء الثاني من هذا العمل إطارا موحدًا لتعدين عمليات الرعاية الصحية يشمل العديد من المستشفيات ومراكز الرعاية الصحية في مدينة مكة المكرمة والمشاعر المقدسة لإجراء تحليل قوي للرعاية الصحية موجه نحو العمليات. يتكون الإطار المقترح من مكونات ومراحل مختلفة لتحليل عمليات الرعاية الصحية وتحسينها بشكل فعال أثناء الأحداث الكبيرة مثل جمع البيانات وتكاملها، وإنشاء سجل الأحداث والمعالجة المسبقة، واكتشاف العمليات وتحليلها، وتخصيص الموارد، وتقييم ما بعد الحدث، وأخيرا الامتثال لجودة الرعاية الصحية والتقارير القائمة على الأدلة. من المتوقع أن يعزز هذا الإطار خدمات الرعاية الصحية، كما هو موضح في الدراسات السابقة عندما تم تطبيقه على البيانات من مركز رعاية صحية واحد.

#### Abstract

Healthcare process mining has gained attention in recent years and has become increasingly relevant to the digitization of healthcare data. The Kingdom of Saudi Arabia hosts annual mass gathering religious events which can pose unique healthcare challenges due to the large number of attendees and the potential for health-related incidents. Applying healthcare process mining to mass gatherings can be a valuable tool for managing and optimizing healthcare services during large-scale events. This research has a novel contribution in highlighting the role of process-oriented healthcare techniques in the context of mass gathering. The presented work consists of two main parts. The first part defines the concept of process mining and explores its benefits in terms of modeling the complexity of healthcare processes,

identifying patterns and anomalies in treatment pathways, and measuring adherence to clinical guidelines. The second part of this work suggests a unified healthcare process mining framework that involves several hospitals and healthcare centers of Makkah City and the holy sites to perform robust process-oriented healthcare analysis. The proposed framework consists of various components and stages to effectively analyze and optimize healthcare processes during large events such as data collection and integration, event log creation and pre-processing, process discovery and analysis, resource allocation, and finally healthcare quality compliance and evidence-based reporting. This framework is expected to enhance healthcare services, as demonstrated in prior studies when it was applied to data from a single healthcare center.

**Keywords:** healthcare process mining, process discovery, service quality, electronic health record, mass gathering

## 1. Introduction

Mass gatherings are occasions marked by a large assembly of individuals at a particular site for a defined purpose during a specific timeframe, which can potentially strain the planning and response capabilities of the host country or community [1]. Such gatherings may involve a single event or a combination of multiple events at various locations, similar to the structure of the Olympics. Mass gatherings encompass a wide variety of events, including sports, music/entertainment, religious gatherings, extensive conferences, and exhibitions, among others. Several key planning recommendations for mass gatherings in the context of COVID-19 were published by WHO on 19 March 2020. This recommendation emphasized the importance of good planning, monitoring, and controlling healthcare provided for people involved in a mass gathering event. To do that, healthcare process mining can play a significant role in ensuring outstanding healthcare service quality .

Process mining [2] is a field of data science that involves the analysis of event data generated during the execution of processes to gain insights into the actual processes, detect patterns, and improve efficiency. The term "process mining" is often associated with business process management and workflow analysis. Using process mining in the healthcare domain has proved its efficiency in unleashing the potential of combining business process analysis and machine learning techniques for gaining better insights into data and workflow .

On the other hand, Healthcare Information Systems (HIS) contain comprehensive data concerning patients' health conditions and the healthcare services provided to them [3]. Various types of data, including text, images, and events, are present in healthcare information systems. Existing literature and applications have explored medical data in diverse forms, such as developing clinical support systems, diagnosing diseases, or analyzing medical images. Despite this, care events have received relatively limited attention compared to other types of medical data studied in recent decades.

One key concept of the healthcare process is the care pathway which is defined as the "sequence of care recommended for patients with similar conditions requiring similar treatment" [4]. A care event refers to any action performed on a patient during treatment, accompanied by timing information. In modern information systems, events are automatically stored in a specific component known as 'event logs,' and these systems are recognized as Process-Aware Information Systems (PAIS). While most HISs do not automatically record care events in a single component, event data is dispersed throughout the system, where each department in a healthcare organization can record its relevant care events [3]. Extracting details from these events can aid in constructing the care process that a patient undergoes .

This research aims to explore the potential and challenges of applying healthcare process mining in the context of Hajj and Umrah. The paper provides a general background of the process mining field and healthcare process mining in

particular. The proposed framework that is anticipated to provide a road map for applying healthcare process mining for mass gathering is explained elaborately. In conclusion, both possible benefits and challenges are discussed highlighting some future directions for healthcare process mining.

## 2. Background

### A. Process Mining (PM)

Process mining [2] is a field of data science that involves the analysis of event data generated during the execution of processes to gain insights into the actual processes, detect patterns, and improve efficiency. The term "process mining" is often associated with business process management and workflow analysis. The cornerstone of process mining is the event log. Process mining relies on event logs or event data that records the activities, decisions, and timestamps of each step in a process. These logs can come from various sources, such as information systems, transactional databases, or application logs.

There are three types of process mining:

1 -Discovery: One of the primary goals of process mining is process discovery, which involves automatically creating a visual representation (process model) of the actual process flow based on the event data. This allows stakeholders to understand how processes are executed in reality.

2 -Conformance Checking:

Process mining enables the comparison of the discovered process model with the intended or ideal process model. Conformance checking helps identify deviations or discrepancies between the expected and actual process executions.

3 -Enhancement: Once the actual process is understood, organizations can use process mining to identify areas for improvement and optimization. This may involve streamlining steps, reducing bottlenecks, or improving overall efficiency. There are several advantages of process mining techniques such as performance analysis, variants and pattern discovering, compliance and auditing, and integration capability with other applications.

Performance analysis in process mining provides quantitative analysis of process performance metrics. This includes measures such as cycle time, throughput, and resource utilization. Stakeholders can use this information to identify areas for improvement or evaluate the impact of changes. Variants and patterns can reveal different variants of a process and identify patterns or trends in process execution. Understanding these variants helps organizations adapt their processes to handle different scenarios or conditions. In regulated industries, process mining can be used for compliance monitoring and auditing. By analyzing event data, organizations can ensure that processes adhere to legal and regulatory requirements.

Process mining is often integrated with other technologies, such as data visualization, machine learning, and predictive analytics, to provide a more comprehensive understanding of processes and enable more advanced analyses. Overall, process mining is a powerful approach for organizations seeking to understand, analyze, and optimize their business processes based on real-world data, fostering continuous improvement and efficiency gains.

### B. Healthcare Process Mining (HPM)

Healthcare organizations are complex systems that encompass various elements, including individuals such as administrators, doctors, patients, and nurses, as well as different departments and clinics within the healthcare process [7]. Consequently, the application of process mining in healthcare poses several challenges. According to [7] challenges can be categorized into two primary areas: data quality and process characteristics.

Data quality issues encompass missing, incorrect (such as disparities between entries and corresponding fields in the system), and imprecise data. For example, precise logging of time data is crucial. Conversely, a significant challenge in process characteristics revolves around case heterogeneity. A case, representing a single care pathway, can be highly diverse due to various patient conditions, unforeseen complications necessitating medical intervention that may alter the pathway, and differing levels of patient adherence to treatment.

The general architecture of applying healthcare process mining is depicted in Figure 1. Four components must have interacted with each other which are care providers for instance hospitals, the healthcare information systems used by these organizations, event logs, and process models that are discovered from event logs and reflect how the care processes are delivered to patients.

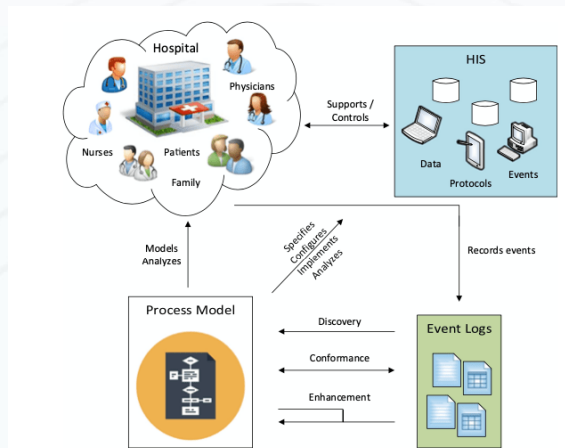


Figure 8: How process mining works in healthcare (adopted from [5] p.3)

### C. Case studies of successful healthcare process mining

The study in [8] focuses on utilizing routinely collected electronic health records to enhance service delivery and clinical research, specifically in the context of patients undergoing chemotherapy. The objectives include establishing reproducible methods for process-mining electronic health records, defining and quantifying patient pathways during chemotherapy, and collecting structured data to inform a cost-effectiveness decision model for home monitoring of neutropenic status during chemotherapy. The researchers analyzed electronic health records from a UK oncology center, focusing on patients with metastatic breast cancer or colorectal cancer who underwent specific chemotherapy between January 2004 and February 2013. The developed software and Markov model revealed significant variance from assumed care pathways. Among the patients studied, only a small percentage completed the planned chemotherapy cycles without unplanned hospital contact, and a substantial number were admitted to the hospital during the treatment period. The findings highlight the complexity of patient pathways during chemotherapy, with a majority deviating from the idealized care pathway. Understanding the real-life clinical pathways through process mining contributes to care and data quality assurance, identifies unmet needs, quantifies the impact of innovations, communicates with stakeholders, and ultimately improves patient care and outcomes .

Another study [9] aims to investigate the role interaction models among healthcare professionals in Emergency Room (ER) processes using process mining techniques. The objectives are to discover role interaction models, understand current collaboration among healthcare professionals, and provide knowledge to enhance ER processes. The four-step method, based on process mining techniques, was applied to a university hospital's ER process using 7160 episodes with



specific attributes. The results reveal insights into how healthcare professionals collaborate in the ER, identifying prevalent role interaction models across major triage categories and specific models for different diagnoses. The study also identifies common and exceptional professional interaction models at the role level. The study effectively employs real-life clinical data and process mining techniques to discover role interaction models in ER processes. The findings offer valuable insights into healthcare professional collaboration, presenting opportunities for process improvement in the ER.

This research [10] highlights the underutilization of business process analysis and process mining, particularly in the healthcare domain. It emphasizes the importance of applied research using these techniques on routinely collected healthcare data to empirically investigate care delivery by different health providers. However, cross-organizational mining and comparative analysis pose further challenges related to population and activity comparability, model visualization, and result interpretation. Without addressing these challenges, the potential benefits of evidence-based process improvement in healthcare may not be realized. The article introduces the nature of healthcare processes, reviews process mining in health literature, and presents a case study exploring the application of process mining techniques to administrative and clinical data for patients with chest pain symptoms in four public hospitals in South Australia. The case study demonstrates an approach providing detailed insights into clinical and fiscal pressures in healthcare delivery. The authors conclude by discussing key lessons learned from their experience in conducting business process analysis and process mining based on data from different hospitals.

### 3. The Proposed Framework of HPM

#### A. The healthcare process mining framework in a mass gathering.

**Step1:** Acquiring access to one or multiple Electronic Health Records (EHR)

The first step of applying this framework is to get access from healthcare providers to invoke the HIS and EHR where most care events are stored in.

**Step2:** Extracting complete event log

An event log should be in the form of row-based data where every row represents a single event with its related attributes, for example, time, position, and caregiver. For instance, admission time, blood pressure measurements, and other vital signs.

**Step3:** Building process model using a process mining tool

Applying process mining discovery techniques to build the process model. In this step, a process mining tool should be selected to investigate various discovery algorithms to build the model. It should be noted that each process discovery algorithm can generate a different model depending on the strategy that is used in the algorithm. Some algorithms focus on determining concurrent events and some of them are designed to cope with the complexity (variability) of the process.

**Step4:** Visualizing and analyzing the generated healthcare model

The generated process model from step 3 can be visualized and animated to demonstrate the real flow of the process. This is the most significant advantage of a process model where it shows the actual flow that has happened, unlike other simulation tools that just illustrate the flow of what-if questions for scenarios that might happen. The generated model can be linked to the current operational dashboard that is used in the holy sites administration center.

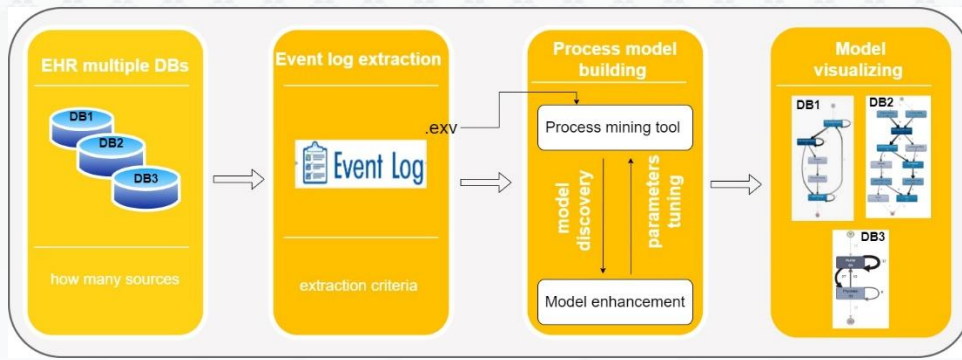


Figure 9: Proposed framework for applying healthcare process mining in mass gathering context

## B. The opportunities and challenges of implementing this framework

healthcare process mining offers a holistic view of operations, enabling healthcare organizations to make informed decisions, improve quality of care, enhance patient experiences, and achieve operational excellence. It is a valuable tool for driving continuous improvement in healthcare delivery processes.

Here are some key benefits:

### 1- Process Visibility:

Understanding Workflow using process mining provides a comprehensive view of healthcare workflows. It allows organizations to visualize and understand how tasks and activities are performed, from patient admission to discharge. Consequently, this helps identify variations in workflows followed, showing where processes deviate from expected pathways. This insight is valuable for standardization and quality improvement.

### 2- Performance Analysis:

Performance tends to be vulnerable to bottlenecks and delays in the flow. Process mining allows for the identification of bottlenecks and delays in healthcare processes. Thus, organizations can pinpoint areas that contribute to longer waiting times or inefficiencies and take targeted actions for improvement.

### 3- Analyzing Resource Utilization:

Healthcare process mining enables the analysis of resource utilization, including staff, equipment, and facilities. By understanding how resources are utilized within processes, healthcare organizations can optimize staffing levels and resource allocation for improved operational efficiency.

### 4- Quality Improvement:

Process mining can be used to monitor compliance with healthcare standards, protocols, and regulations. This is crucial for ensuring that care delivery aligns with established guidelines.

### 5- Reducing Errors:

By analyzing processes, healthcare organizations can identify and address potential sources of errors or lapses in quality, leading to improved patient safety and outcomes.

### 6- Optimizing Patient Pathways:

Enhancing patient experience by understanding patient journeys through process mining helps in optimizing patient pathways. This can lead to a more positive and streamlined experience for patients, reducing wait times and improving satisfaction.

#### 7- Care Coordination:

Process mining aids in analyzing and optimizing care coordination among different healthcare providers, enhancing the continuity of care for patients.

#### 8- Evidence-Based Decision-Making:

Healthcare process mining is based on real-time data, providing an evidence-based foundation for decision-making. It allows healthcare leaders to make informed decisions and implement changes backed by data-driven insights.

**Continuous Improvement:** The continuous monitoring and analysis of healthcare processes enable organizations to adopt a culture of continuous improvement, adapting to changing needs and evolving best practices.

#### 9- Operational Efficiency:

Process mining helps in identifying redundant or non-value-added steps in healthcare processes, enabling organizations to streamline workflows and reduce unnecessary complexities.

#### 10- Risk Mitigation and Compliance:

Process mining can aid in detecting irregularities or patterns indicative of fraud or unethical practices, contributing to fraud prevention and compliance. **Auditing and Accountability:** The ability to trace and audit processes enhances accountability, ensuring that healthcare providers adhere to established protocols and ethical standards.

Despite the discussed above opportunities, there are several challenges of healthcare process mining in a mass gathering context. This section highlights the key differences between applying process mining in mass-gathering medicine and regular healthcare, emphasizing the unique challenges and considerations in each context.

1. **Scale and Complexity:** The mass gathering context involves large crowds, dynamic environments, and unpredictable situations. Typically operates at a smaller scale with more controlled environments.
2. **Dynamic and Unpredictable Environments:** encountering sudden spikes in demand, emergencies, and dynamic incidents. More stable and planned, with occasional emergencies.
3. **Resource Allocation and Logistics:** to ensure this aspect, it requires efficient deployment of personnel and resources in real-time while resource allocation in regular healthcare process mining is usually stable and planned in advance.
4. **Collaboration Across Agencies:** Involves collaboration between various agencies, event organizers, healthcare providers, and emergency services. Collaboration is common but may involve fewer stakeholders.
5. **Public Health Surveillance:** to tackle this challenge, a strong focus should be on monitoring and managing public health aspects during the event. Unlike normal healthcare process mining where ongoing surveillance has less focus on specific events.
6. **Temporary Medical Facilities:** Involves setting up, managing, and dismantling temporary medical facilities. Permanent healthcare facilities with established processes.

## 4. Results

The example presented here is to demonstrate the value of HPM in modeling three different outcomes for patients with COVID-19. Two cohorts of adult inpatients (aged  $\geq 18$  years) from King Faisal Specialist Hospital & Research (KFSH) were included in this retrospective cohort research (Riyadh) [12]. All adult COVID-19 patients diagnosed according to WHO interim guidance were screened, and those who died or were released between January 1, 2020, and July 23, 2020, were included in our study. Seventeen patients hospitalized with COVID-19 were included in this retrospective study. Ten out of seventeen of these patients which are 58.8 % were in the normal D-Dimer range whilst seven out of seventeen i.e.

41.2% fell in the higher range causing them to be at risk. All seventeen patients exhibited a good respiratory rate despite the differences in the D-Dimer range. From the extracted data 12/17 (71%) patients had a normal range of lymphocyte counts, whilst 5/17 (29%) patients exhibited a lymphocyte count that was at risk.

We evaluated the clinical course of asymptomatic and symptomatic patients with laboratory-confirmed coronavirus disease (COVID-19) admitted. In Figure 3, a cohort of 25 patients, 18 (72 %) had symptoms at admission whilst (28 %) were asymptomatic. Nine (50%) out of the symptomatic patients had no cure, whereas the remaining 9 (50%) were given a cure. Six (86%) of the asymptomatic patients were given a cure whilst one (14%) patient wasn't given a cure. In total, 15/25 (60%) were given a cure whilst 10/25(40%) received no cure. Seven of the patients who were receiving a cure were then admitted into ICU and the remaining eight were not admitted to ICU. From the sample of 10 patients who were not receiving a cure, six (60%) were admitted to ICU, and 4(40%) were not admitted to ICU. In total, 12/25 (48%) were not in ICU whilst 13/25(52%) were. Ten patients that weren't in ICU ended up surviving and eight that were in ICU also survived giving us a total of 18/25 (72%) survivors. On the other hand, 3/13 of the patients that were in ICU did not survive and an additional 2 of the patients that weren't in ICU (2/12) also didn't survive. Thus, giving us a total of 5 deaths which is equivalent to 20% of the cohort. Two of the patients (8%) from the ICU were in isolation.

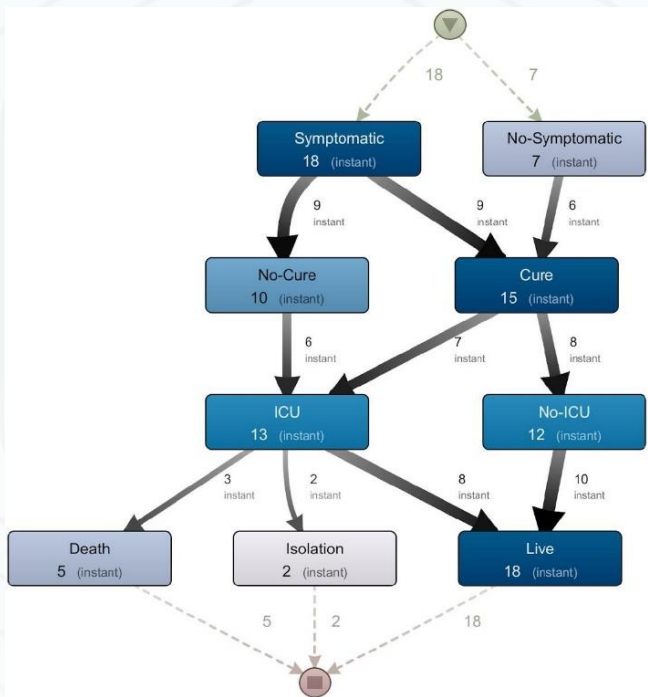


Figure 10: The pathway of patients hospitalized with COVID-19 depends on who has symptomatic and non-symptomatic (this model is adopted from [12])

## 5. Conclusions

In conclusion, the application of healthcare process mining in the context of mass gatherings presents a transformative potential for the healthcare landscape during events such as Hajj and Umrah. The benefits are manifold, as evidenced by the improved modeling of clinical pathways, increased visibility into healthcare processes, and the ability to pinpoint and mitigate bottlenecks within the system. The detection of process variations and deviations further contributes to understanding the dynamic healthcare environment during large-scale gatherings, ultimately resulting in enhanced service quality.

Nevertheless, the adoption of healthcare process mining in the context of mass gatherings is not without its challenges. One of the key hurdles lies in coordinating access to event logs, especially when dealing with data from multiple sources. The integration of diverse systems to generate an event log suitable for model discovery demands careful consideration and collaborative efforts. Addressing these challenges is imperative for realizing the full potential of healthcare process mining in mass-gathering scenarios.

As we look forward, overcoming these obstacles will not only pave the way for refined healthcare processes during such events but will also significantly contribute to enriching the overall participant experience. The continuous advancement of research and technology will be instrumental in tackling these challenges, facilitating the seamless integration of healthcare process mining in the unique and complex dynamics of mass gatherings. Future endeavors in this field hold the promise of not only optimizing healthcare delivery but also ensuring the well-being and satisfaction of participants on a larger scale.

## References

1. [World Health Organization. Public health for mass gatherings: key considerations (Interim Guidance) (<https://apps.who.int/iris/rest/bitstreams/717805/retrieve> , 1 December 2023)
2. W. M. P. van der Aalst, *Process Mining: Data Science in Action*. Springer Berlin Heidelberg, 2016. [Online]. Available: <https://books.google.co.uk/books?id=hUEGDAAAQBAJ>
3. Ronny S Mans, Wil MP Van der Aalst, and Rob JB Vanwersch. *Process mining in healthcare: Evaluating and exploiting operational healthcare processes*. Springer, 2015.
4. Owen Johnson, Thamer Ba Dhafari, Angelina Kurniati, Frank Fox, and Eric Rojas. The clearpath method for care pathway process mining and simulation. In *International Conference on Business Process Management*, pages 239–250. Springer, 2018.
5. Eric Rojas, Jorge Munoz-Gama, Marcos Sep´ulveda, and Daniel Capurro. Process mining in healthcare: A literature review. *Journal of Biomedical Informatics*, 61:224–236, 2016
6. T. Zhao, H. Ye, U. K. Mukherjee, and D. Chhajer. Demand estimation of mass-gathering healthcare in developing countries: The case of Kumbh Mela in India. *Naval Research Logistics* 68(8):995–1017, 2021.
7. Payam Homayounfar. Process mining challenges in hospital information systems. In *Federated Conference on Computer Science and Information Systems (FedCSIS)*, pages 1135–1140. IEEE, 2012.
8. Karl Baker, Elaine Dunwoodie, Richard Jones, Alex Newsham, Owen Johnson, Christopher Price, Jane Wolstenholme, Jose Leal, Patrick McGinley, Chris Twelves, and Geo Hall. Process mining routinely collected electronic health records to dene real-life clinical pathways during chemotherapy. *International Journal of Medical Informatics*, 103:32{41}2017.
9. Camilo Alvarez, Eric Rojas, Michael Arias, Jorge Munoz-Gama, Marcos Sep´ulveda, Valeria Herskovic, and Daniel Capurro. Discovering role interaction models in the emergency room using process mining. *Journal of Biomedical Informatics*, 78:60–77, 2018.

10. Partington, A., Wynn, M., Suriadi, S., Ouyang, C. and Karnon, J., 2015. Process mining for clinical processes: a comparative analysis of four Australian hospitals. *ACM Transactions on Management Information Systems (TMIS)*, 5(4), pp.1-18.
11. Cancer diagnostic delay reduction – Spain, Universitario Lucus Augusti (HULA), case study report 2018.
12. Eman Alghamdi, Najwa Alshahrani, Amirah Alharbi. Clinical course and risk factors for mortality of adult in patients with COVID-19 in KFSH, Riyadh , *In preparation*.





## Implementing Achievement Challenges Strategy at the Hajj to Enhance User Experience: A Mobile App-Driven Digital Transformation Approach

Najwa H Samrgandi

Data Science Department, Umm Al-Qura University

\*Corresponding author: E-mail (nhsamrgandi@uqu.edu.sa)

### تنفيذ استراتيجية تحدي الإنجاز في الحج لتعزيز تجربة المستخدم: نهج التحول الرقمي القائم على تطبيقات الجوال

نجوى حسين سمرقندي

قسم علم البيانات، جامعة أم القرى

#### الملخص

الحج رحلة روحية عميقة يقوم بها المسلمون من كافة انحاء العالم، لكن يحدث فيه العديد من التحديات والتي من بينها المناخ والحرارة. تركز الدراسة على دعم التحول الرقمي باستخدام تطبيق الهاتف المحمول من خلال تفعيل استراتيجية تحدي الإنجاز والتي تتمثل في تنفيذ تحدي يقوم على المحافظة على الترطيب بالمياه لمواجهة التحديات الصحية المرتبطة بتغير المناخ أثناء فترة الحج. يهدف استخدام التطبيق إلى تحسين تجربة المستفيد وتنظيم إدارة الحشود من خلال الحصول على المعلومات الشخصية والبيانات الفعلية والمشاركة المجتمعية. وتهتم الاستراتيجية المبتكرة في الدراسة على الحفاظ على مستوى الترطيب الملائم للجسم للتخفيف من مخاطر الجفاف والإجهاد الحراري وتشجع المستخدمين على تبادل تجاربهم وتقديم الدعم المتبادل. كخاصية إضافية مميزة في تطبيق استراتيجية تحدي الإنجاز يتم تطبيق نظام المكافآت التشجيعية والذي يتمثل في الحصول على عيوات من ماء زمزم عند تحقيق معايير الترطيب اللازمة من خلال إبرام الاتفاقيات أو الحصول على الرعاية حيث إن هذا النوع من المكافآت لا يشجع على المشاركة فحسب، بل يرتبط بأهمية الدينية لفريضة الحج. يعتمد تنفيذ تحدي الإنجاز أيضا على المعلومات الشخصية التي تأخذ في الاعتبار متغيرات مثل العمر والظروف الصحية والطقس. ويتيح تطبيق الهاتف المحمول للمستخدمين مراقبة حالة الترطيب لديهم والحصول على تحديثات الطقس بشكل مباشر مما يساهم في تخصيص الخيارات بناء على المعطيات المتاحة. كما يوفر التطبيق خريطة توضح أماكن ومصادر توفر المياه القريبة والصالحة للشرب، بالإضافة إلى الإشعارات التي تذكر المستخدمين باستهلاك المياه بالكميات المناسبة والتي يمكن تقسيمها على فترات زمنية يتم تحديدها مسبقًا.

تشير الدراسات السابقة إلى أهمية التحول الرقمي وتجربة المستخدم في إدارة الحشود خلال الحج، مستشهدة بأمثلة على تطبيقات الجوال التي عملت على تحسين تجربة الحاج. حيث تناولت إحدى الدراسات موضوع تحديات المناخ خلال الحج، مع التأكيد على ضرورة التنبؤات الجوية الدقيقة والتدابير الوقائية. بالإضافة إلى استكشاف دور الحلول الرقمية في تعزيز مشاركة المجتمع، وإبراز التأثير الإيجابي للتحول الرقمي. استخدمت الدراسة المنهج الوصفي لشرح تصميم التطبيق المقترح، وتوضيح إطار الدراسة، والمتغيرات والضوابط والإجراءات، وأساليب تقييم النموذج. يتضمن إطار الدراسة مكونات رئيسية مثل مراقبة الرطوبة، وتحديثات الطقس، ومكافآت ماء زمزم، ومعلومات المستخدم، ومشاركة المجتمع. يقدم قسم النتائج نماذج لمواجهة التطبيق، مع توضيح للشاشة الرئيسية، وشاشة التحديات، وشاشة الخريطة. تهدف النماذج إلى ضمان سهولة تجربة المستخدم والتركيز على التفاعل، والتحديات، وخصائص الخريطة. وقد تم

مناقشة الية تنفيذ خصائص رئيسية مثل تسجيل المستخدم، ولوحة التحديات، ونظام المكافآت، وتحديثات الطقس المتزامنة، ومراقبة الرطوبة، والخريطة التفاعلية، ومشاركة المجتمع. وتؤكد الدراسة على أهمية التقييم المستمر والمراجعات الدورية لضمان تحقيق متطلبات المستخدم حيث تسلط الضوء على العلاقة بين التحول الرقمي وتجربة المستخدم ومدى فعالية استراتيجية إنجاز التحدي في الحج.

وتُختتم الدراسة بملخص للنتائج والمساهمات الرئيسية، مبرزة النهج المبتكر لاستراتيجية "تحقيق التحديات" في معالجة التحديات المتعلقة بالحج. يُشير العمل المستقبلي إلى توسيع قاعدة المستخدمين، وتحسين التخصيص باستخدام خوارزميات الذكاء الاصطناعي، والتطوير المستمر بناءً على احتياجات المستخدمين، والشراكات التعاونية، وتحليل البيانات العميق. يُعتبر تنفيذ تحديات الحج من خلال تطبيق الجوال خطوة رائدة نحو تعزيز تجربة الحجاج بشكل عام، مع إمكانية المزيد من التقدم في المجالات ذات الصلة.

## Abstract

Muslims from all over the world travel to perform the Hajj, which is a profound spiritual journey but also one that has many challenges, such as the heat and weather. This study delves into the facilitation of digital transformation through a mobile application, employing the Achievement Challenges strategy. The primary focus revolves around addressing health issues induced by climate change, particularly dehydration, by setting hydration challenges during the Hajj pilgrimage. The application's overarching goal is to elevate the user experience and streamline crowd management by harnessing personal data, real-time information, and community involvement. The study introduces an innovative strategy emphasizing the importance of maintaining optimal hydration levels to mitigate the risks of dehydration and heat stress. It actively encourages users to share their experiences and provide mutual support. A distinctive feature of the Achievement Challenges strategy is the incorporation of an incentive rewards system. This system rewards users with Zamzam water bottles upon achieving hydration standards, reinforcing participation and aligning with the religious significance of Hajj.

The successful implementation of the Achievement Challenges hinges on personalized information, considering variables such as age, health conditions, and weather. The mobile application empowers users to monitor their hydration status and receive real-time weather updates, contributing to tailor-made recommendations. Additionally, the app features a map highlighting nearby drinking water sources and periodic notifications reminding users to consume water adequately.

The literature review underscores the pivotal role of digital transformation and user experience in managing the Hajj population. It cites examples of mobile apps that have significantly improved pilgrim experiences. The challenges posed by climate conditions during Hajj are addressed, underlining the crucial need for accurate meteorological predictions and preventive measures. The study explores the transformative impact of digital tools in fostering community participation. The methodology section adopts a descriptive approach to elucidate the proposed mobile application design. It incorporates a conceptual framework, variables and controls, materials, procedures, and an evaluation method/prototype. Key components of the study framework include hydration monitoring, weather updates, Zamzam water rewards, user information, and community participation. The results section presents wireframes illustrating the application interface, encompassing the home screen, challenges screen, and map screen. These wireframes are meticulously designed to ensure a clear and intuitive user experience, emphasizing engagement, challenges, and map features. The study delves into the implementation of key features, such as user registration, achievement challenges dashboard, incentive rewards system, real-time weather updates, hydration monitoring, interactive map, and community engagement.



The study concludes by summarizing key findings and contributions, highlighting the innovative nature of the Achievement Challenges strategy in addressing Hajj-related challenges. Future work is outlined, envisioning the expansion of the user base, enhanced personalization through AI algorithms, continuous iterative development based on user feedback, collaborative partnerships, and in-depth data analysis. The implementation of Hajj Achievement Challenges through a mobile application is deemed a pioneering step toward enriching the overall pilgrim experience, with the potential for further advancements in related fields.

**Keywords:** Improving the User Experience, Digital transformation, the Achievement Challenges strategy, Mobile App-Driven.

## 1. Introduction

The annual pilgrimage to Makkah is a spiritual and transforming experience for Muslims worldwide. However, extreme temperatures and unpredictable weather patterns pose specific challenges. Drought- and heat-related health conditions are a major concern for the Hajj. Pilgrims are often exposed to dangers due to the large and crowded pilgrimage sites, as well as difficult weather conditions. This hinders pilgrims' religious obligations, and health problems may arise due to dehydration and heat stress. Therefore, this research investigates the implementation of the concept of achievement challenges in the idea of a mobile application to enhance the user experience in Hajj.

### Research Problem:

The detrimental consequences of heat stress and dryness during Hajj are the main research issues this study attempts to solve. Additionally, it involves identifying the suitable approach through mobile applications to establish hydration challenges that encourage users to preserve an optimal quantity of water, hence reducing the health hazards linked to severe weather conditions. This study seeks to investigate the correlation between digital transformation and user experience, as well as the effectiveness of implementing the accomplishment challenges approach in the context of Hajj.

### The Objectives:

1. Assess the effectiveness of the Achievement Challenges Strategy in increasing and maintaining hydration levels among Hajj participants:
  - Assess the incentive rewards system's impact on user involvement and dedication to the hydration challenge, particularly the distribution of Zamzam water.
  - Evaluate the strategy's impact on climate-related health issues during Hajj.
2. Enhance user experience through digital transformation:
  - Examine how the mobile app enhances the Hajj participant experience:  
The app's function is crowd management, data collection, and community participation.
    - Evaluate user happiness with real-time weather updates, individualized hydration monitoring, and notifications for optimal water consumption.
  - 2. Examine the Partnership Between Digital Transformation and User Experience:
    - Examine how digital initiatives, like mobile app-driven strategies, impact the user experience during the Hajj journey.
    - Explore how the mobile app's personal data, real-time statistics, and community involvement make Hajj more organized and enjoyable.

- Evaluate how the innovative digital approach fits into religious pilgrimage digital transformation.

### The Research Questions:

- How does the Achievement Challenges strategy, facilitated by a mobile app-based digital transformation method, impact Hajj participants' hydration habits?
- How does implementing an incentive rewards system, such as Zamzam water bottles for hydration challenges, impact user participation, engagement, and digital transformation strategy effectiveness in improving Hajj pilgrimage experiences?

### Literature Review

Hajj AR 9, an augmented reality mobile app, guides pilgrims to holy locations and performs Hajj rituals using 3D maps for a novel and varied experience (Felemban, E. et al., 2020). Interactive, educational, and organized, the app overcomes mobile app limitations. Toddlers read better with larger letters and less static information. The Hajj AR 9 mobile app offers a unique and diverse AR experience. Not all Hajj mobile apps are organized, informative, and interactive (Madi M., Albakry S., and Ibrahim N., 2020). A pilgrims' dictionary, a Dua and Zikr smartphone app, and a multilingual translation system for real-time linguistic support are Hajj mobile apps.

According to Majrashi (2018), Hajj 2017 pilgrims loved mobile apps. The study provided measures to improve the Hajj mobile app user experience. It found that way-finding instruction and training, Google Maps integration, and bracelet monitoring chips improved Hajj pilgrims' experiences. Real-time language assistance and social media integration in Hajj smartphone apps would let pilgrims communicate.

The mobile app provides advice, real-time language support, augmented reality to explore holy locations and rites, and interactive features for pilgrims of all ages (Liu, S. et al., 2021). To enrich pilgrims' spiritual journey and make Hajj memorable, the Hajj mobile app integrates past study recommendations and fixes mobile app issues. Their study recommends pilgrim way-finding training, improved pedestrian pathways and facilities, Google Maps, and tracking chips that link pilgrim bracelets to features. Thus, a mobile app-driven digital transformation and Achievement Challenges plan can improve Hajj crowd management and the user experience. Mobile apps with navigation, real-time language help, social media integration, sensory data, and context-based personalized services can improve Hajj pilgrimage experiences (Shaout, A., & Khan, S., 2016). Achievement Challenges strategy using a mobile app-driven digital transformation approach at the Hajj can personalize services, improve crowd management, and encourage community participation and mutual support, making the pilgrimage more efficient and enjoyable (Quaium, A. et al., 2023).

### Climate Challenges at Hajj

Given climate-related Hajj issues, imaginative methods are needed to protect pilgrims' physical and mental health. Giving pilgrims accurate meteorological predictions and current information helps them plan their journeys and take necessary precautions (Almuzaini et al., 2022). These projections can be shared via Facebook, Twitter, WhatsApp, text messaging, billboards, and mobile apps.

Heat safety precautions include shaded zones and cool resting areas for pilgrims to relax and hydrate (Alsayed et al., 2021). These methods can prevent heatstroke and other heat-related illnesses. Mahdi et al. (2022) also stress the importance of pilgrims' hygiene. Hand sanitization, hand hygiene, and waste management are promoted to prevent communicable diseases. Innovative tactics and preventive measures can reduce Hajj pilgrims' health risks. Additionally,

government, non-profit, and religious collaborations are crucial to providing thorough pre-travel teaching and assistance to pilgrims who are especially at risk.

### **User Experience and Digital Transformation**

User experience and digital transformation improve population management during Hajj, a global pilgrimage. User experience and digital transformation have become increasingly important in Hajj population management. The Hajj pilgrimage, which draws millions of Muslims from around the world, is a major event (Majrashi, 2018). User experience and digital transformation are essential for population control during the Hajj pilgrimage when millions of Muslims congregate in Makkah. The above items help pilgrims navigate the path, provide vital information, and ensure a safe and successful journey (Jakaj & Toci, 2022). Governments may improve population management and pilgrimage experiences by using digital technologies and focusing on user experience (Grandi et al. (2021)

Digital transformation and user experience are essential for Hajj population management. According to Reis & Melão (2023), these aspects can help pilgrims navigate, provide vital information, and provide a safe and efficient experience for all attendees. Manual and automated Hajj functions are needed to serve different user groups (Majrashi, 2018).

Digital transformation and user experience are essential for Hajj population management. These components facilitate pilgrim movement, provide user advice, and ensure a safe and successful experience for all guests (Gómez & Viniegra, 2018). Digital transformation and user experience help manage people during the Hajj trip by simplifying movement, providing vital information and direction, and ensuring a safe and successful experience. Considering pilgrims' different technology preferences and concerns, Hajj smartphone apps must include both manual and automatic counters to control crowds (Majrashi, 2018).

### **Community Participation in Digital Solutions**

Digital solutions have changed society and community participation (Stodolka et al., 2023). Digital tools promote community engagement, collaboration, and decision-making (Calabrese et al., 2021). Digital solutions make information more available, increase networking, and let people shape their communities (Zhang & Wen, 2023). Communities should participate in decision-making for numerous reasons. First, community involvement empowers. Respecting their opinions improves satisfaction and results. Second, communal decision-making enhances credibility. Participation in the community improves decision-making. Digital platforms affect urban planning community engagement, according to Wilson et al. (2019). The study found that internet platforms enabled community members to voice their perspectives, making decision-making more inclusive and transparent.

Another 2023 study by Sarwar B. et al. evaluated social media community membership. The study found that social media transformed people's lives by allowing community members to talk, exchange ideas, and provide input on many issues. Mohammed et al. (2019) explored how online forums and discussion boards might involve communities in decision-making. The study found that these online platforms allowed community members like students to voice their opinions, discuss ideas, and communicate, leading to more inclusive and collaborative decision-making.

Mobile apps can engage communities in environmental conservation, according to Johnson et al. (2021) mobile apps help community members collect, communicate, and collaborate on environmental monitoring and conservation. Digital platforms and technologies increase community participation by increasing communication, collaboration, and engagement, according to research.

### **Evaluating Digital Transformation Strategies**

McKinsey concluded that digital transformation methods can boost EBITDA by 20–30%. A clear digital strategy and the skills needed for change were underlined in the report (McKinsey, 2018). A Harvard Business Review study studied digital change and consumer experience. Digital transformation-savvy organizations have happier customers and more profits (Rethinking Digital Transformation - Harvard Business Review, 2020).

Many sectors are embracing digital change. As the digital world grows, businesses must evaluate their digital transformation efforts. Given the fast-changing digital world and significant technological breakthroughs, enterprises must review their digital transformation efforts. Many academic studies have looked at the need to review digital transformation strategies to ensure they meet corporate goals and achieve results. Scholars have underlined the importance of developing evaluation criteria and metrics for digital transformation's impact on KPIs (Yusof et al., 2022). Companies must integrate digital technology in today's fast-changing world. According to Tonder et al. (2020), companies across all industries are investing more in digital technologies to grow, improve customer experiences, optimize operations, and stay competitive. Assessment of digital transformation strategies is essential to achieving organizational goals. Digital transformation plans must be assessed by understanding how digital technology influences company elements. Digital transformation can impact customer engagement, employee productivity, operational efficiency, and company performance. Many sectors prioritize digital transformation (Zeng & Lei, 2021). Consider these methods' strengths and weaknesses to assess them. A comprehensive literature study illuminates digital transformation evaluation methods and frameworks.

## 2. Methodology

The descriptive methodology is employed to elucidate the phenomena, as it serves to depict the proposed mobile application design for the implementation of the achievement challenges approach during the Hajj pilgrimage, to augment the user experience.

### The study Framework:

#### 1. Conceptual Framework

##### 1. Mobile App Components:

###### a. The Hydration Monitoring feature:

- Allow users to input their water consumption.
- Track and analyze user hydration via algorithm-driven monitoring.

###### b. Weather updates:

- Real-time weather API integration for reliable weather data.
- Weather notifications for Hajj heat and weather issues.

###### c. Zamzam Water Rewards System:

- Allow users to create and accomplish hydration goals.
- Zamzam water bottle incentives through partnerships or sponsorships.

###### d. User Information and Community Participation:

- Personal user profiles, including age and health conditions.
- Community involvement elements like forums and sharing platforms for user support and experience sharing.

#### 2. App architecture interconnections:

a. Hydration Monitoring and Weather Updates:

- Real-time weather-based algorithmic modifications to hydration recommendations.
- Weather notifications affect user hydration goals.

B. Zamzam Water Rewards System and User Data:

- User profiles affect individualized hydration challenges.
- Rewards based on user data encourage involvement and adherence.

c. Community Participation and Achievement Challenges: - Community input shapes challenge design.

-Experiences helping reach hydration goals together.

**3. Achievement Challenges Integration:**

a. User Data Integration: Adjust Achievement Challenges based on user profiles.

- User-generated data shaping hydration challenges.

b. Real-Time Weather Information: Utilize weather data to address climate-related concerns.

- Weather affects hydration notification timing and type.

c. Community Challenge Engagement:

- Social features for challenge system community participation.
- Group achievement challenges.

**4. Integration Overview:**

a. User Sets Personal Hydration Challenge:

- Users enter age and health circumstances to influence hydration goal recommendations.

The challenge is adjusted for climate by real-time weather.

b. Community Challenge Participation:

- Users participate in shared experiences and support-based challenges.
- Community feedback shapes challenge design and difficulty.

c. Implementing the Incentive Rewards System:

- App tracks hydration standards.
- Sponsorships ease Zamzam water bottle distribution as prizes.

**5. UX Improvement:**

a. Customized Recommendations:

- Personalized hydration recommendations based on user profiles and weather data.
- Personalization and context-aware notifications improve user experience.

b. Crowd Management: Encouraging communal accountability for community challenges.

- Rewards for hydration compliance improve crowd well-being.

**6. Digital Transformation Impact:**

a. Organized Crowd Management: Aids in arranging communal challenges.

- Personal data collection helps users organize and tailor their experience.

b. Digital Transformation and User Experience:

- How digital tools, personalized recommendations, and community interaction increase user experience.
- How the software supports and advances digital transformation in the Hajj pilgrimage setting.

## 2. Variables and Controls:

### a. User Variables:

#### Definition and Categorization:

- demographic information, focusing on age, and health conditions. Age is categorized into groups (e.g., 18-30, 31-45, 46 and above) for analysis.
- Health conditions

#### Privacy Controls and Data Security Measures:

- through secure user authentication and authorization protocols.

### b. Weather Data Control:

#### Sources and Reliability of Real-time Weather Data:

- Real-time weather
- Multiple sources are cross-referenced

#### App Controls and Updates Weather Information:

- updates from designated weather sources.
- An automatic validation mechanism

### c. Hydration Monitoring Controls:

#### Algorithms and Mechanisms for Monitoring User Hydration:

- algorithms that consider user-inputted data age, and health conditions.
- physiological algorithms to estimate hydration levels

#### Accuracy and Privacy of User-inputted Data:

- data is securely stored and encrypted
- Hydration monitoring algorithms undergo regular validation against established hydration measurement methods.

## 3. Materials:

### a. Mobile Application Development:

- Technologies and Frameworks:
- User Interface and Experience Design Considerations:

### b. Zamzam Water Rewards System:

- Mechanisms for Obtaining Zamzam Water:
- Transparency and Fairness in Reward Distribution:

## 4. Procedures:

### a. User Registration and Data Collection:

- Step-by-Step Process:
- Data Protection Measures

b. Hydration Monitoring Procedures

- Notifications and Hydration Input
- Real-Time Monitoring Algorithms

c. Zamzam Water Rewards System Implementation:

- Reward Protocol
- Partnership Agreements or Sponsorships

5. Evaluation Method/Prototype:

- a. User Experience Assessment
- b. Effectiveness of Achievement Challenges
- c. Digital Transformation Impact
- d. Religious Significance Evaluation

**3. Results and Discussion:** In line with the research focus on supporting digital transformation during the Hajj pilgrimage, a mobile application has been discussed to implement the Achievement Challenges strategy. The app aims to enhance user experience, address health challenges related to climate conditions, and contribute to effective crowd management.

**Wireframes:** The following are wireframes for three essential screens (Table 1):

- a. Home Screen:
- b. Challenges Screen:
- c. Map Screen:

Table 1. Comparative Schedule: The App Wireframes

Feature	Home Screen	Challenges Screen	Map Screen
Head	-App logo on the left. -User profile on the right indicating hydration status.	-Back button to return to home screen. -Title: "Ongoing Challenges."	-Back button to return to home screen. -Title: "Drinking Water Stations Map." Map: -Interactive map showing locations of water stations.
Main Content	Content: -Featured Achievement Challenge: "Stay Hydrated During Hajj." -Quick links to ongoing challenges and rewards -Real-time weather updates prominently displayed.	Challenges List: -Challenge card displays the challenge name, description, and progress. -"Join" button for participation -Filter option for completed challenges.	-Pin markers with details about each station. Filter and Search: -Options to filter stations by type (e.g., sponsored community-driven). -Search bar for specific locations
Navigation	-Bottom navigation bar with icons for Home, Challenges, Map, and Profile.	-Bottom navigation bar remains accessible.	-Bottom navigation bar for seamless navigation.
CTA (Call to Action)	-"Join the Challenge" button for immediate user engagement.	-"Create Your Challenge" button for user-generated challenges	—

a. Home Screen:

The Home Screen focuses on user engagement, featuring the "Join the Challenge" button prominently displayed. Users can quickly access ongoing challenges, rewards, and real-time weather updates.

### b. Challenges Screen:

The Challenges Screen allows users to explore ongoing challenges, join them, and create their own challenges. Users can filter completed challenges and track their progress through challenge cards.

### c. Map Screen:

The Map Screen provides a visual representation of water stations, offering interactive features for filtering and searching. Users can filter stations by type and search for specific locations, promoting efficient access to drinking water. These wireframes provide a visual representation of the suggested layout for the mobile app screens. The wireframes aim to ensure a clear and intuitive user experience, emphasizing the key elements of the Achievement Challenges strategy while addressing the specific needs of Hajj participants. Figure 1 shows an example of the user interfaces of the implemented application. The login page for the mobile application, designed to implement the Achievement Challenges strategy at the Hajj, is meticulously crafted to provide a seamless and secure entry point for users. Users can log in using traditional credentials such as email and password. Additionally, the option for social media login may be provided for added convenience.

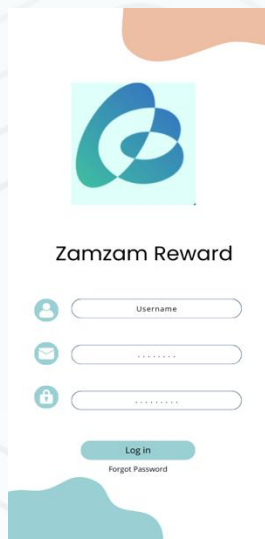


Figure 1. Application Interface

### Key Features and Implementation:

#### 1. User Registration and Personalization:

- Users provide personal information securely, influencing hydration goal recommendations.
- Customized user profiles offer individualized experiences.

#### 2. Achievement Challenges Dashboard:

- A central dashboard displays current and future challenges.
- Challenges focus on hydration, incorporating real-time weather updates.

#### 3. Incentive Rewards System:

- The app features a rewards system based on hydration standards.
- Virtual rewards and physical Zamzam water bottles serve as incentives.

#### 4. Real-Time Weather Updates:

- Reliable weather data is delivered through reputable APIs.



- Push notifications help users plan and adjust hydration goals based on weather changes.

5. Hydration Monitoring and Notifications:

- The app tracks hydration levels based on user input.
- Automatic reminders encourage users to drink water at set intervals.

6. Interactive Map for Drinking Water Stations:

- The map displays the locations of nearby water stations.
- Users can explore and contribute information about water sources.

7. Community Engagement Features:

- Social features enable users to share experiences and support each other.
- Gamification promotes achievement and teamwork.

8. Evaluation and Analytics:

- Analytics tools track user engagement, challenge completion rates, and app usage.
- Continuous evaluation and user input inform iterative improvements.

**Result and Impact:**

The study has revealed that the mobile application effectively addresses health issues and fosters a sense of community and spiritual involvement among Hajj participants (Table 2). The incentive rewards system, linked to the religious importance of Zamzam water, has proven effective in promoting active engagement. Early user input anticipates heightened awareness of water requirements, improved health outcomes, and strengthened camaraderie among pilgrims. The app's impact on digital transformation is evident in the implementation of simplified crowd management through real-time data integration and personalized recommendations.

Ongoing assessments and regular revisions are crucial to ensuring the adaptability of the mobile application to user requirements, contributing to the overall success of the Hajj season achievement challenges plan. This study underscores the interdependent connection between digital transformation, user experience, and innovative techniques applied to address distinct challenges within the context of Hajj.

Table 2. Key Findings and Contributions

	Key Findings	Contributions
1	Achievement Challenges Effectiveness	<ul style="list-style-type: none"> <li>- Innovative learning method with motivational incentives.</li> <li>- Promotes active engagement and a sense of accomplishment.</li> </ul>
2	Incentive Rewards System Impact	<ul style="list-style-type: none"> <li>- Zamzam water's religious significance enhances motivation.</li> <li>- Demonstrates efficacy in promoting user participation.</li> </ul>
3	Personalization and Community Interaction	<ul style="list-style-type: none"> <li>- Personalized advice and tailored solutions improve user experience.</li> <li>- Community forums and gamification foster a sense of community.</li> </ul>
4	Digital Transformation and User Experience	<ul style="list-style-type: none"> <li>- Simplified crowd management through real-time data integration.</li> <li>- Enhances individual spiritual experiences during the Hajj pilgrimage.</li> </ul>

**4. Conclusions**

The study concludes with a pioneering exploration of mobile application-based digital transformation employing the Hajj Achievement Challenges technique. Key findings underscore the effectiveness of innovative learning methods, the

influence of religiously significant incentives, and the positive outcomes derived from personalized and community-driven features. The comparative analysis with prior studies further reinforces the distinctive and successful nature of the integrated approach.

#### 1. Effectiveness of Achievement Challenges:

The implementation of Achievement Challenges within the mobile application has showcased innovative learning methods complemented by motivational incentives. This outcome resonates with Majrashi's (2018) findings, emphasizing the positive impact of gamification and the challenges in enhancing user engagement during the Hajj pilgrimage.

#### 2. Impact of Incentive Rewards System:

The integration of Zamzam water bottles as incentives within the rewards system has proven highly effective, with the added enhancement of motivation through the religious significance attached to Zamzam water. This observation aligns with the findings of Quaium et al. (2023), underscoring the importance of incorporating cultural and religious elements in digital solutions for pilgrimage experiences.

#### 3. Personalization and Community Interaction:

The provision of personalized advice and tailored solutions within the mobile application has significantly elevated the overall user experience. Consistent with similar positive outcomes in studies by Liu et al. (2021) and Madi et al. (2020), this underscores the crucial role of interactive and community-driven features in Hajj mobile applications.

#### 4. Digital Transformation and Enhanced User Experience:

The digital transformation facilitated by the mobile application has streamlined crowd management through comprehensive real-time data integration. This includes features such as real-time weather updates, individualized hydration monitoring, and notifications for optimal water consumption. This resonates with Majrashi's (2018) findings, associating improved user experience with features like real-time language assistance and GPS integration.

### Comparative Analysis with Previous Studies

Comparing our findings with those of previous studies, our mobile application demonstrates a holistic approach by combining Achievement Challenges, incentive rewards, personalization, and community interaction. This comprehensive strategy stands out as an effective solution for addressing health challenges and enhancing user experience during Hajj.

This study contributes to the ongoing discourse on improving pilgrimage experiences through technology. By addressing health concerns and promoting digital transformation, our mobile application stands as a valuable tool for future Hajj seasons. Continuous assessments and user input will further refine the application, ensuring its adaptability and success in facilitating spiritual journeys for Muslim pilgrims.

### 5. Future Work

#### 1. Expanded User Base:

- Develop the app to serve diverse demographics and cultural contexts within the Muslim community.

#### 2. Improved Personalization:

- Use AI algorithms to dynamically adjust personalization to individual preferences and health conditions.

#### 3. Continuous Iterative Development:

- Utilize user feedback and new technology to keep the app current and responsive.

#### 4. Collaborative Partnerships:

- Partner with health organizations, sponsors, and religious institutions to expand the application's impact.

#### 5. Conduct thorough data analysis:

- Understand user behavior, difficulties, and the long-term impact of the app on pilgrims' health and well-being.

#### 6. Accessibility and Inclusivity:

- Guarantee application accessibility for various users, including language support, accessibility features, and technology literacy considerations.

Implementing Hajj Achievement Challenges through a mobile application is a pioneering step towards improving the overall pilgrim experience. Researchers and developers may continue to develop technical solutions related to the Hajj journey by embracing future work in related fields.

### References

1. Almuzani, Y., Alburayh, M., Alahmari, A., Alamri, F., Sabbagh, A Y., Alsalamah, M., & Khan, A. (2022). Mitigation strategies for heat-related illness during mass gatherings: Hajj experience. <https://scite.ai/reports/10.3389/fpubh.2022.957576>
2. Calabrese, M., Sala, A L., Fuller, R., & Laudando, A. (2021) Digital Platform Ecosystems for Sustainable Innovation: Toward a New Meta-Organizational Model? <https://scite.ai/reports/10.3390/admsci11040119>
3. Felemban, E., Rehman, F U., Biabani, S A A., Ahmad, A., Naseer, A., Majid, A R M A., Hussain, O K., Qamar, A., Falemban, R., & Zanjir, F. (2020). Digital Revolution for Hajj Crowd Management: A Technology Survey. <https://scite.ai/reports/10.1109/access.2020.3037396>
4. Gómez, I J., & Vinięra, L M. (2018). Ofertas de empleo mejor remuneradas en comunicaci3n y diseo: nuevos perfiles y efecto full-stack. <https://scite.ai/reports/10.31921/doxacom.n27a12>
5. Grandi, F., Khamaisi, R K., Peruzzini, M., Raffaelli, R., & Pellicciari, M. (2021). A Reference Framework to Combine Model-Based Design and AR to Improve Social Sustainability. <https://scite.ai/reports/10.3390/su13042031>
6. Jakaj, B., & Toçi, E. (2022). A Brief Review of Healthcare System Transformation Directions. <https://scite.ai/reports/10.47191/ijcsrr/v5-i12-32>
7. Johnson N., Druckenmiller M., Danielsen F., Pulsifer P. (2021) The Use of Digital Platforms for Community-Based Monitoring, *BioScience*, Volume 71(5) 452-466. <https://doi.org/10.1093/biosci/biaa162>
8. Liu, S., Cao, Y., Xu, J., & Zeng, W. (2021). Realization of Mobile Augmented Reality System Based on Image Recognition. <https://scite.ai/reports/10.32604/jihpp.2021.017254>
9. Mahdi, H A., Rashid, H., Qashqari, F S., Hariri, S., Marglani, O., Barasheed, O., Albutti, A., Alwashmi, A S S., Shaban, R Z., Booy, R., & Alfelali, M. (2022). Syndromic surveillance of respiratory-tract infections and hand hygiene practice among pilgrims attended Hajj in 2021: a cohort study. <https://scite.ai/reports/10.1186/s12879-022-07559-0>
10. Madi, N A M., Albakry, N S., & Ibrahim, N. (2020). AR Mobile Application in Learning Hajj for Children in Malaysia: A Preliminary Study. <https://scite.ai/reports/10.3991/ijim.v14i16.12807>
11. Majrashi, K. (2018). User need and experience of Hajj mobile and ubiquitous systems: Designing for the largest religious annual gathering. <https://doi.org/10.1080/23311916.2018.1480303>
12. Mohammed, S., Onyema, E., Deborah, E., Alsayed, A., & Mohammed, Q. (2019) Online discussion forum as a tool for interactive learning and communication. *International Journal of Recent Technology and Engineering (IJRTE)*, 8(4), 4852-4868. <https://doi.org/10.35940/ijrte.d8062.118419>

13. Quaium, A., Al-Nabhan, N., Rahaman, M., Salim, S I., Noor, J., Hossain, M A., Islam, N., Mostak, A., Islam, M S., Mushfiq, M M., Jahan, I., & Islam, A B M A A. (2023). Towards associating negative experiences and recommendations reported by Hajj pilgrims in a mass-scale survey. <https://scite.ai/reports/10.1016/j.heliyon.2023.e15486>
14. Reis, J., & Melão, N. (2023). Digital transformation: A meta-review and guidelines for future research. <https://scite.ai/reports/10.1016/j.heliyon.2023.e12834>
15. Rethinking Digital Transformation - Harvard Business Review. (2020). <https://hbr.org/sponsored/2020/03/rethinking-digital-transformation>
16. Sarwar B., Sarwar A., Al-Rahmi., Almogren A., Salloum S., & Habes M. (2023) Social media paradox: Utilizing social media technology for creating better value for better social outcomes: Case of developing countries, *Cogent Business & Management*, 10:2, DOI: 10.1080/23311975.2023.2210888
17. Shaout, A., & Khan, S. (2016). ALHAJJ "HAJJ APP FOR IOS. <https://doi.org/10.31436/iiumej.v17i1.528>
18. Shambour, M K Y., & Gutub, A. (2021). Personal Privacy Evaluation of Smart Devices Applications Serving Hajj and Umrah Rituals. <https://scite.ai/reports/10.36909/jer.13199>
19. Stodolka, W., Mayer, J., Duparc, E., & Steffen, B. (2023) The Stakeholder Onboarding Model: Addressing the Challenges of Multi-Stakeholder Onboarding. <https://scite.ai/reports/10.1051/itmconf/20235105002>
20. Taibah, H., Arlikatti, S., Andrew, S A., Maghelal, P., & DelGrosso, B. (2020). Health information, attitudes and actions at religious venues: Evidence from hajj pilgrims. <https://doi.org/10.1016/j.ijdr.2020.1018>
21. The keys to a successful digital transformation | McKinsey. (2018). <https://www.mckinsey.com/capabilities/people-and-organizational-performance/our-insights/unlocking-success-in-digital-transformations>
22. Tonder, C V., Schachtebeck, C., Nieuwenhuizen, C., & Bossink, B. (2020). A framework for digital transformation and business model innovation. <https://scite.ai/reports/10.30924/mjcmi.25.2.6>
23. Wilson, A., Tewdwr-Jones, M., & Comber, R. (2019) Urban planning, public participation and digital technology: App development as a method of generating citizen involvement in local planning processes. *Environment and Planning B: Urban Analytics and City Science*, 46(2), 286-302. <https://doi.org/10.1177/2399808317712515>
24. Yusof, N., Hashim, N L., & Hussain, A. (2022). A Conceptual User Experience Evaluation Model on Online Systems. <https://scite.ai/reports/10.14569/ijacsa.2022.0130153>
25. Zeng, G., & Lei, L. (2021). Digital Transformation and Corporate Total Factor Productivity: Empirical Evidence Based on Listed Enterprises. <https://scite.ai/reports/10.1155/2021/9155861>
26. Zhang, Y., & Wen, B. (2023) Internet Platform Enterprises and Farmers Digital Literacy Improvement. <https://scite.ai/reports/10.1051/shsconf/202315204003>



## Modeling and Simulation of an Integrated System for Providing Medical Services for Pilgrims and Umrah Visitors through Medical Centers and Telemedicine

Mohamed S. Yasein\*, Esam Ali Khan

The Custodian of the Two Holy Mosques Institute of Hajj and Umrah Research, Umm Al-Qura University.

\*Corresponding author: E-mail (myasein@uqu.edu.sa)

## نمذجة ومحاكاة لنظام متكامل لتقديم الخدمات الطبية للحجاج والمعتمرين من خلال المراكز الطبية وخدمات الطب عن بعد

محمد صديق ياسين\*, عصام علي خان

معهد خادم الحرمين الشريفين لبحاث الحج والعمرة، جامعة أم القرى

### الملخص

يعدّ الحج والعمرة من أكبر التجمعات الجماهيرية والأحداث الكبيرة في العالم، حيث يشارك فيها ملايين المسلمين كل عام. وغالبًا ما يواجه الحجاج تحديات صحية بسبب عوامل مختلفة مثل الإجهاد الحراري والأزدحام والحالات المرضية الموجودة مسبقًا. والعدد الكبير من الحجاج والزوار يجعل توفير الرعاية الطبية الكافية تحدياً كبيراً. ولكن لا ينبغي أن تطغى المخاوف الصحية على الأهمية الروحية لأداء المنسك. لذلك، من الضروري التأكد من سلامة الحجاج وصحتهم من خلال تقديم خدمات طبية فعالة. إحدى طرق تحسين كفاءة وفعالية الخدمات الطبية للحجاج والمعتمرين تتمثل في تطوير وتنفيذ نظام متكامل يشمل المراكز الطبية الفعلية وخدمات الطب عن بعد. يمكن لهذا النظام أن يوفر للحجاج والزوار رعاية طبية عالية الجودة وفي الوقت المناسب، بغض النظر عن موقعهم. وتشمل مكونات النظام المتكامل المراكز الطبية الموجودة في المدينتين المقدستين في مكة والمدينة، خدمات الطب عن بعد التي يمكن للحجاج الاستفادة منها للتواصل عن بعد مع مقدمي الرعاية الصحية عند الضرورة، وشبكات اتصال موثوقة.

تركز هذه الورقة البحثية على عرض نموذج محاكاة لنظام متكامل يقدم خدمات الرعاية الصحية من خلال المراكز الطبية وخدمات التطبيق عن بعد. لتقييم أداء النظام المتكامل، يتم اختبار تأثير إجراء عدة تعديلات بمتغيرات النظام في سيناريوهات المحاكاة. يتم قياس تأثيرات التغييرات من خلال عدد من مؤشرات أداء، مثل أوقات انتظار المريض، ومدة بقاء المرضى بالنظام، وعدد حالات المرضى المفتوحة/النشطة/المغلقة، بالإضافة إلى كفاءة إشغال الأطباء. وأظهرت نتائج المحاكاة أن استخدام مثل هذه الأنظمة المتكاملة يمكن أن يضمن تعزيز تدفق العمليات، وتحسين الموارد، وبالتالي ضمان التعامل بفعالية مع الطلب الكبير على الخدمات الطبية خلال مواسم الحج والعمرة.

### Abstract

Hajj and Umrah are two of the world's largest mass gatherings and mega events, with millions of Muslims participating each year. Pilgrims often face health challenges due to factors such as heat stress, overcrowding, and pre-existing medical conditions. The large number of pilgrims and visitors makes it challenging to provide medical care sufficiently. The

spiritual significance of these journeys should not be overshadowed by health concerns. Therefore, it is vital to make sure that pilgrims are safe and healthy by providing efficient medical services. One way to improve the efficiency and effectiveness of medical services for pilgrims and Umrah visitors is to develop and implement an integrated system that includes physical medical centers and telemedicine services. Such a system could provide pilgrims and visitors with timely and high-quality medical care, regardless of their location. The components of the integrated system include medical centers that are located in the holy cities of Makkah and Madinah, telemedicine services that can be utilized by pilgrims to connect remotely with healthcare providers when necessary, and reliable communication networks. This paper focuses on demonstrating a simulation model of an integrated system that provides healthcare services through medical centers and telemedicine services. To evaluate the performance of the integrated system, several flow modifications are reflected in the simulation scenarios. The effects of variations are measured using several key performance indicators, including patient waiting times, patient cycle time, the number of opened, active, and closed patient cases, as well as physician utilization. Simulation results show that utilizing such integrated systems can ensure enhanced process flow, resource optimization, and consequently timely medical assistance.

**Keywords:** Modeling and Simulation, Medical Centers, Telemedicine, Pilgrims

## 1. Introduction

Hajj is one of the world's greatest mass gatherings that every year attracts millions of Muslims from all over the world to the Saudi holy city of Makkah. It is a significant spiritual journey that has enormous meaning to Muslims. While the journey is a time for spiritual meditation, solidarity, and worship, it also involves challenges, especially in the field of healthcare. Ensuring the health and well-being of millions of pilgrims during Hajj is a challenging task that needs detailed preparation, coordination, and delivery of healthcare services.

Effective planning and communication are essential for all stakeholders, particularly the government of the Kingdom of Saudi Arabia, the Ministry of Health (MOH), the Ministry of Hajj and Umrah, and other relevant agencies. Hajj planners must work in coordination with local medical facilities, clinics, ambulance and emergency services to enable transfers, referrals, and other essential services. Plans are also required in case of a mass casualty disaster or serious emergency. Because so many people are congregating in one place at once, it is important to account for peak demand at all local medical institutions to make sure that they can handle any potential increase in attendance. While global mass gatherings and mega events offer valuable insights, Hajj is a distinct event with particular challenges due to its extended duration (Alrufaidi, 2023).

Hajj is a physically demanding ritual for pilgrims because they may have to walk several kilometers in a crowd, which can be exhausting. Additionally, pilgrims may experience heat exhaustion due to the typically hot weather. In general, there are several public health concerns associated with this large assembly, such as the spread of infectious diseases, accidents and injuries, and health issues linked to the environmental conditions (Yezli, 2022).

Mass gathering medicine addresses a wide range of health risks related to these gatherings. Infectious and non-infectious diseases, injury, and illness caused by the environment are among the risks (Almehmadi, 2023).

As an example, global sporting events have received a lot of attention in the research on mass gatherings. Events like the Olympics and the World Cup not only occur frequently and attract millions of visitors, but they also take place in different locations, allowing for the collection of diverse insights. In addition, religious events, such as Hajj, are a type of mass gathering that is particularly large in terms of participation and is concentrated in specific geographical locations.

According to religious studies, the Muslim population is the fastest growing in the world, with a 35% increase expected over the next 20 years. By 2030, the global Muslim population is expected to reach 2.2 billion, more than doubling the rate of non-Muslims (Almehmadi, 2023). To align with this increase in Muslim population, Saudi vision 2030 is targeting serving 30 millions visitors during Hajj and Umrah seasons every year (Saudi Vision 2030).

Regarding Hajj, there might be some health risks associated with organizing the event. The mass gathering has several characteristics that contribute to a risky environment for health. First, the size and density of the pilgrim crowds significantly increases the risk of pilgrims contaminating each other with infections and causing physical harm to each other through stampedes. The size of the gathering is complicated further by the fact that Makkah is limited in area. Furthermore, the diversity of the Hajj pilgrim population raises the level of health risk during the mass gathering. Hajj pilgrims come from all over the world, and their medical backgrounds are as varied as they are unique (Almehmadi, 2023).

During Hajj seasons, the relevant authorities use a range of services that attempt to prevent health issues. According to earlier research, pilgrims who visit medical facilities during Hajj experience a range of illnesses, such as heat stroke, respiratory conditions, and cardiovascular disease (Alrufaidi, 2023). The Saudi government provides free health services for pilgrims. To guarantee that pilgrims have access to medical services during Hajj season, the authorities have designated hospitals, including both permanent and temporary medical centers, and tens of thousands of qualified healthcare professionals and volunteers for this purpose. Patients are typically admitted to hospitals and medical centers in Makkah, Madinah, as well as the holy sites of Mina, Arafat and Muzdalifah. Critical cases are transferred to advanced care units in the primary hospitals in the area when necessary (Memish, 2012).

While these health service resources appear to be substantial, there might still a gap in comparison to the millions of pilgrims they are intended to serve. One way to improve the efficiency and effectiveness of medical services for pilgrims and Umrah visitors is to develop and implement an integrated system that includes physical medical centers and telemedicine services. Such a system could provide pilgrims and visitors with timely and high-quality medical care, regardless of their location. The components of the integrated system include medical centers that are located in the holy cities of Makkah and Madinah, telemedicine services that can be utilized by pilgrims to connect remotely with healthcare providers when necessary, and reliable communication networks.

This paper aims to utilize computer modeling and simulation to study the effectiveness of integrating telemedicine with the healthcare services of physical medical centers. The goal of the integrated system is to provide pilgrims and Umrah visitors with efficient medical services. To evaluate the performance of the integrated system, several flow variations are reflected in the simulation scenarios. The effects of these variations are measured using several key performance indicators, including patient waiting times, patient cycle time, the number of opened, active, and closed patient cases, as well as physician utilization, in several simulation scenarios.

The paper is organized as follows: Section-2 discusses telemedicine as a means of providing healthcare services. Section-3 presents the computer modeling of the integrated system for providing healthcare services, while simulation results and discussion are presented in Section-4. Conclusions are drawn in Section-5. Finally, recommendations are presented in Section-6.

## 2. Telemedicine as a means of providing healthcare services

During Hajj and Umrah seasons, the relevant authorities use a range of services that attempt to guarantee that pilgrims and visitors have access to medical services. They designat hospitals and medical centers, in addition to the qualified

healthcare professionals and volunteers for this purpose (Aljohani, 2022). While these health resources appear to be substantial, there might still be a gap in comparison to the millions of pilgrims they are intended to serve.

Technological advancements have induced profound transformations in various domains of Hajj and Umrah. In the healthcare sector, telemedicine has undergone significant development, emerging as a pivotal approach for addressing medical needs and delivering immediate care.

Telemedicine stands as a potential solution to the aforementioned challenge, offering pilgrims access to high-quality healthcare services remotely. Leveraging technology and online communication, telemedicine acts as a bridge between patients and healthcare providers. This approach enables healthcare providers to diagnose, consult with, and advise patients without necessitating physical visits to hospitals or medical centers, thereby enhancing the accessibility and convenience of healthcare services. It has many uses across diverse applications encompassing diagnosis, treatment, monitoring, and education. Telemedicine proves particularly advantageous for pilgrims facing challenges in accessing conventional healthcare services, including individuals with chronic health conditions or those residing in remote geographical locations. Telemedicine provides a number of options for improving healthcare delivery during the Hajj and Umrah. Pilgrims can use telemedicine to have remote consultations with healthcare professionals and receive advice on how to manage health conditions while performing their rituals. Furthermore, telemedicine makes it easier to provide reminders for medication adherence and other treatment plans. Pilgrims can also participate in educational programs that address Hajj-related health risks and prevention strategies. Many healthcare systems have launched initiatives to deliver healthcare services directly to patients through digital applications (apps). In the United States, entities such as American Well, Teladoc, and Doctor on Demand offer e-consultations encompassing diagnostic and treatment-related services. Similarly, in the United Kingdom, GP at Hand facilitates video consultations for patients residing in the city of London (Alharbi, 2021). Moreover, most countries hosting large-scale events implement healthcare technologies for the assessment of disease risks, complementing traditional surveillance methods, notably leveraging telemedicine. For instance, in the context of the FIFA World Cup 2022, heightened telemedicine utilization, encompassing virtual and e-services for consultations, was used to address challenges arising from the event. This approach aimed to minimize the impact on patient access to healthcare and ensure the continuity of care (Dergaa, 2023). A distribution of 70% virtual consultations to 30% face-to-face consultations was instituted during the event, strategically utilizing e-services and online sessions to facilitate consultations for residents and non-residents while mitigating foot traffic at healthcare centers. Additionally, unless an in-person meeting is deemed necessary by the physician, all initial and follow-up appointments were scheduled as virtual consultations (Dergaa, 2023).

In the realm of Saudi efforts in the field of telemedicine, the report titled “Telehealth Application Guidelines” was issued by the National Health Information Center to serve as an essential document for organizing telehealth practices in the Kingdom of Saudi Arabia, ensuring both safety and efficiency in telehealth services (National, 2023). It aims to develop telehealth practice guidelines for healthcare professionals, virtual hospitals, and mobile apps. As a result, it covers the requirements for telehealth services, the basic steps for using telehealth services, patient rights, and telehealth technical requirements. Indeed, the report is not intended to be a clinical guideline for any specific specialty or disease, but rather to assist healthcare professionals in providing the best care to patients through the use of telehealth technologies (National, 2023). Furthermore, the Ministry of Health is expanding the telemedicine services within the country by incorporating advanced technologies into healthcare delivery. In this pursuit, an e-health application named “Seha” was introduced in 2018, enabling individuals to engage in face-to-face visual medical consultations with their physicians



through smartphones. The application is structured to facilitate audio-video communication, allowing users to log in, directly interact with specialists, and undergo case diagnosis within the application. Consequently, specialists address user inquiries, conduct necessary medical consultations, and administer required medical procedures (Alharbi, 2021).

### 3. Modeling of the integrated system for providing healthcare services

Within the healthcare sector, simulation is extensively employed and stands out as a crucial tool for operational research. This methodology allows researchers to navigate the inherent variability and uncertainty present in healthcare systems with remarkable flexibility (Ahmad, 2020). Additionally, the integration of a graphical user interface enhances decision-making processes and simplifies result interpretation. These attributes collectively position simulation as a useful technique frequently employed by healthcare practitioners to investigate intricate processes, organizational dynamics, and human behavior (Ahmad, 2020).

In healthcare facilities setting, where processes are complex and variations make analysis challenging, simulation is a useful tool. For example, in (Ahmad, 2020), a research that analyzes an existing health care system in Pakistan using SIMIO simulation software, identify areas for improvement and suggest alternative system was proposed. Another research in (Bedoya-Valencia, 2016) employed a simulation model to analyze the operations of a medium-sized emergency department. The goal of the simulation model was to examine how the Emergency Department (ED) allocates its resources to shorten patient lengths of stay while maintaining efficient resource usage.

#### 3.1 Problem Formulation

The issue addressed in this study focuses on computer modeling of an integrated system that provides healthcare services through medical centers and telemedicine. It is assumed that the operations in the medical center include the following: admitting patients (with a rate of  $P_{MC}$ ), registration, consultation with an available physician, directing the patient to any additional examinations (X-Ray, Ultrasound, etc.) if needed, directing the patient to the pharmacy, and finally, the patient leaving the center. On the other hand, it is assumed that the processes in the telemedicine system include the following: admitting patients into the online system (with a rate of  $P_{Tele}$ ), registration, consultation with an available physician, directing the patient to a physical medical center if needed (with a rate of  $\alpha.P_{Tele}$ ), directing the patient to a community pharmacy, and finally, the patient leaving the system. The outline of the processes in both medical centers and telemedicine services are shown in Figure 1. The system behavior is affected by several parameters, such as the admission rate of patients, the number of registrars, the number of physicians, etc. The effects of variations in these parameters need to be assessed. This can be achieved by building a computer model of the integrated system and carrying out simulation scenarios to measure the required key performance indicators.

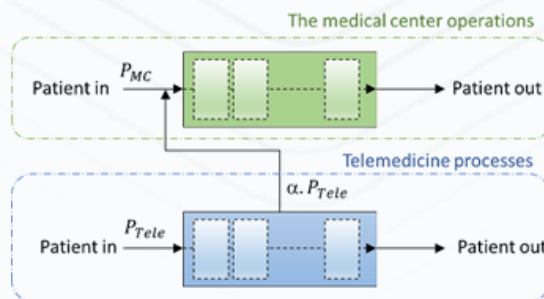


Figure 1. The outline of the processes in medical centers and telemedicine services.

### 3.2 Building the Model of the integrated system for providing healthcare services

The next step involves constructing the model by developing schematics and network diagrams of the integrated healthcare services system. This includes abstracting the essential features of the system and programming its operations to characterize its functionality. In the constructed model, the parameters affecting the behavior of the system are as follows:

- patients' admission rate to the medical center (and to the telemedicine service),
- capacity of the waiting area,
- the number of registrars in the medical center (and in the telemedicine service),
- the number of physicians in the medical center ,
- the number of pharmacists in the medical center,
- the number of the telemedicine consultants,
- referral ratio to the medical center from the telemedicine service,
- registration time in the medical center (and in the telemedicine service),
- consultation time in the medical center (and in the telemedicine service),
- waiting time in the pharmacy in the medical center,
- referral ratio to the additional examinations, and
- waiting time in the additional examinations.

The effects of system parameter variations are measured using several key performance indicators, including the following:

- patient waiting times (before and after registration, and at the pharmacy),
- patient cycle time, which is the total time spent in the medical center (or in the telemedicine service),
- the number of opened, active, and closed patient cases, and
- physician utilization.

The simulation model was created by translating the model formulation with the use of Anylogic Software, which is a multi-method simulation tool with an intuitive GUI. It enables combining process modeling, system dynamics and agent-based modeling in one model. The layout of a typical medical center was considered in developing the simulation model. The general structure of the model's processes is illustrated in Figure 2, while Figure 3 provides a snapshot of the model (in 2D and 3D), depicting the layout of the medical center and the flow of patients.

### 4. Simulation results

Through a series of simulation scenarios, the model's behavior is analyzed. The conducted simulations aim to assess the effects of variations in system parameters, such as the admission rate of patients, the number of physicians, etc., on the performance of the integrated healthcare services system in terms of key performance indicators, such as patient waiting time, patient cycle time, and physician utilization. Examples of these simulation scenarios are presented and discussed in the following sub-sections. Table 1 summarizes the system parameters used in these simulation scenarios. The parameters varied in different scenarios are bolded in the table.

The first parameter shown in Table 1 is the arrival patterns for patients' admission rates to the medical center (and to the telemedicine service). Examples of the used patients' arrival patterns are shown in Table 2. For the times parameters, the

triangular distribution is used. The values shown in each parameter is the maximum and minimum values, in addition to the most likely case (Kissell, 2017).

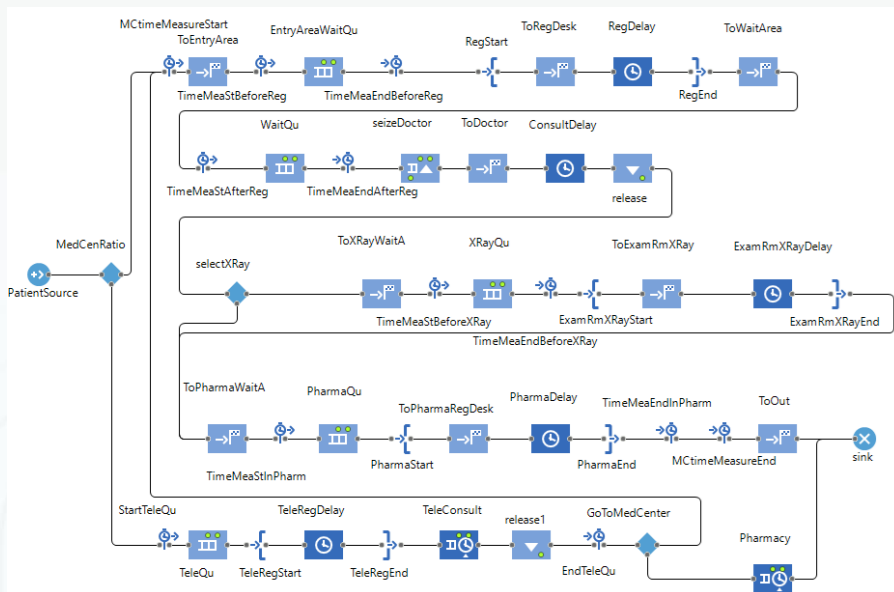


Figure 2. The processes structure of the model.

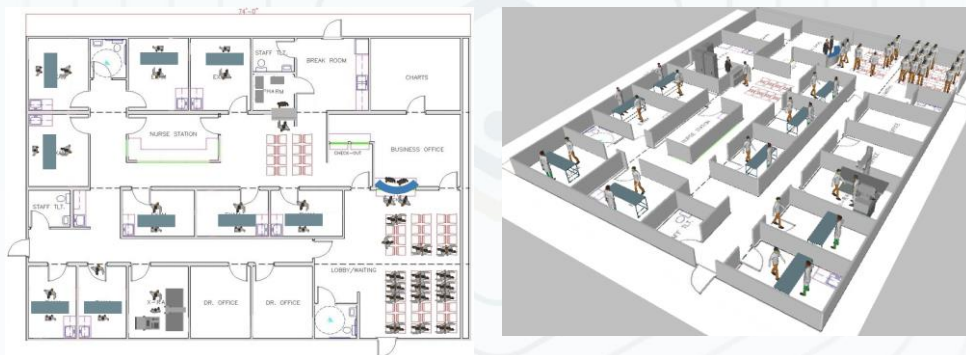


Figure 3. A snapshot of the simulation model (in 2D and 3D).

Table 1. System parameters used in the different Scenarios.

Parameter	Scenario 1			Scenario 2			Scenario 3			Scenario 4		
Patients' arrival pattern	$S_0$	$S_1$	$S_2$	$S_0$			$S_0$			$S_0$		
The telemedicine patients' arrival ratio	~50%			~50%	~70%	~80%	~70%			~70%		
The number of registrars in the medical center	3			3			3			3		
The number of registrars in the telemedicine service	3			3			3			3		
The number of physicians in the medical center	9			9			9	6	3	6		
The number of the telemedicine consultants	9			9			9	12	15	12		
The number of pharmacists in the medical center	3			3			3			3		
The referral rate to the medical center from the telemedicine service	~30%			~30%			~30%			~30%	~20%	~10%
The referral rate to the additional examinations	~20%			~20%			~20%			~20%		
The registration time in the medical center (min.)	Triangular (2,3,4)			(same)			(same)			(same)		

The registration time in the telemedicine service (min.)	Triangular (2,3,4)	(same)	(same)	(same)
The consultation time in the medical center (min.)	Triangular (8,10,12)	(same)	(same)	(same)
The consultation time in the telemedicine service (min.)	Triangular (10,12,14)	(same)	(same)	(same)
The waiting time in the pharmacy (min.)	Triangular (2,3,4)	(same)	(same)	(same)
The waiting time in the additional examinations (min.)	Triangular (10,20,30)	(same)	(same)	(same)

Table 2. Examples of the used patients' arrival patterns.

Arrival pattern			
symbol	$S_0$	$S_1$	$S_2$

**4.1 Scenario-1:** In this simulation scenario, the model was tested over a duration of 8 hours using the system parameters listed in Table 1. However, the examination focuses on the variation in the patients' arrival pattern. The results of a simulation experiment using ( $S_0$ ) are shown in Figures 4-7. The waiting time distribution in the medical center is illustrated in Figure 4, while Figure 5 depicts key statistics related to the overall performance in the medical center. Specifically, it shows the distribution the total time spent in the center, as well as the total number of opened, active, and closed patient cases. On the other hand, Figure 6 depicts key statistics related to the overall performance of the telemedicine service. Specifically, it shows the distribution of the total time spent in the system, as well as the total number of initiated, active, and closed patient cases. In Figure 7, statistics of the overall performance of the integrated system (in the medical center and at the telemedicine services) are illustrated, where the average utilization of physicians is shown in Figure 7(a), while Figure 7(b) depicts the total number of open, active, and closed patient cases. The summary of the simulation results using different patients' arrival patterns ( $S_0$ ,  $S_1$ , and  $S_2$ ) is shown in Table 3. The results of the simulation experiment demonstrate that, based on the system parameters employed, a high patients' arrival rate ( $S_1$ ) increases the average utilization of physicians, as required. However, this also places a load on the system, as illustrated by the extended total time spent within the system. Conversely, the opposite is observed for a lower patients' arrival rate ( $S_2$ ), as depicted in Table 3. Therefore, for the given system parameters, an optimal patients' arrival rate is denoted as ( $S_0$ ). However, a higher patients' arrival rate could be served (as shown for the ( $S_1$ ) case), but it necessitates an increase in the number of physicians for a reasonable waiting time.

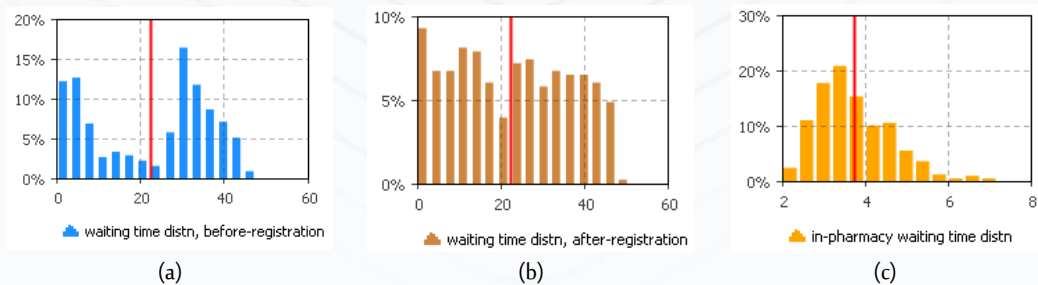
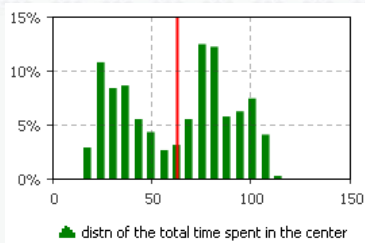
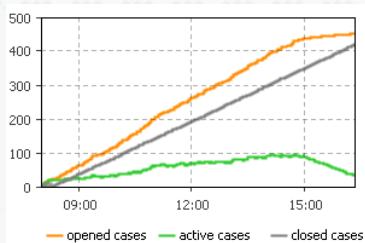


Figure 4. The waiting time distributions in the medical center: (a) before-registration waiting time distribution, (b) after-registration waiting time distribution, and (c) in-pharmacy waiting time distribution.



(a)

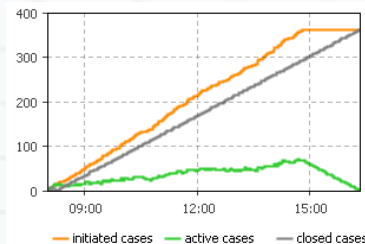


(b)

Figure 5. Statistics of the overall performance of the medical center: (a) distribution of the total time spent in the center, and (b) the total number of opened, active, and closed patient cases.

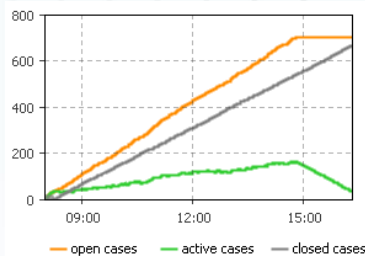


(a)

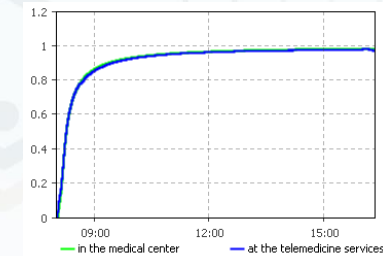


(b)

Figure 6. Statistics of the overall performance of the telemedicine service: (a) distribution of the total time spent in the system, and (b) the total number of initiated, active, and closed patient cases.



(a)



(b)

Figure 7. Statistics of the overall performance of the integrated system (in the medical center and at the telemedicine services): (a) physicians average-utilization, and (b) the total number of open, active, and closed patient cases.

Table 3. The simulation results, using different patients' arrival patterns.

KPI	Scenario 1								
	Patients' arrival pattern								
	S <sub>0</sub>			S <sub>1</sub> ↑			S <sub>2</sub> ↓		
	Med. C.	Tele.	Total	Med. C.	Tele.	Total	Med. C.	Tele.	Total
No. of patients, started (initiated) service	338	362	700	537	513	1050	165	185	350
No. of closed cases	418	361	666	418	361	670	229	185	350
No. of patients, directed to Med. C. from Tele.	113	-	-	109	-	-	64	-	-
No. of active cases	33	1	34	228	152	380	0	0	0
physicians average-utilization	98%	96%	-	98%↑	98%↑	-	64%↓	60%↓	-
Total time spent in the center (min.)	63.4	49.9	-	116.5↑	114.0↑	-	18.3↓	15.4↓	-

**4.2 Scenario-2:** In this simulation scenario, the model was tested over 8 hours using the system parameters listed in Table 1. However, the examination focuses on the variation in the telemedicine patients' arrival ratio. The telemedicine patients' arrival ratio is used to control the approximate portion of patients who choose to go to the medical center directly versus those who choose to initiate a telemedicine service. For example, a value of 70% means that about 70% of the patients go to telemedicine, while around 30% go to the medical center. The summary of the simulation results using different telemedicine patients' arrival ratios (approximately 50%, 70%, and 80%) is shown in Table 4. The results demonstrate that, based on the system parameters employed, the higher the admission ratio to the telemedicine service, the greater the average utilization of physicians at the telemedicine service, and conversely, the lower the average utilization of physicians in the medical center. Consequently, this imbalance affects the resulting time spent in the system, which can be noticed in the results shown in Table 4. Addressing this issue can be achieved by controlling the number of physicians in both the medical center and the telemedicine service, as can be demonstrated in the following simulation scenario.

Table 4. The simulation results, using different telemedicine patients' arrival ratio.

KPI	Scenario 2 (Patients' arrival ratio to Tele.)								
	~50%			~70% ↑			~80% ↑		
	Med. C.	Tele.	Total	Med. C.	Tele.	Total	Med. C.	Tele.	Total
No. of patients, started (initiated) service	338	362	700	237	463	700	123	577	700
No. of closed cases	418	361	666	345	360	596	234	363	481
No. of patients, directed to Med. C. from Tele.	113	-	-	109	-	-	116	-	-
No. of active cases	33	1	34	1	103	104	5	214	219
physicians average-utilization	98%	96%	-	79% ↓	98% ↑	-	54% ↓	98% ↑	-
Total time spent in the center (min.)	63.4	49.9	-	24.2 ↓	98.0 ↑	-	17.9 ↓	115.3 ↑	-

**4.3 Scenario-3:** In this simulation scenario, the model was tested over 8 hours using the system parameters listed in Table 1. However, the examination focuses on the variation in the number of physicians in both the medical center and the telemedicine service. The summary of the simulation results using different combination of the number of physicians in the medical center, and at the telemedicine service, as (9, 9), (6, 12), and (3, 15) is shown in Table 5. The results demonstrate that, clearly, the higher the number of physicians, the lower the average utilization of physicians, and the less time patients spend in the system. However, having a higher average physician utilization is economically favorable, but this increases the overall time spent within the system. Therefore, an optimal solution could be achieved by controlling the number of physicians, considering the available resources, and at the same time ensuring a reasonable amount of time spent within the system.

Table 5. The simulation results, using different number of physicians in both the medical center and telemedicine service.

KPI	Scenario 3 (Patients' arrival ratio to Tele., No. of physicians in Med. C., No. of physicians in Tele.)								
	(~70%, 9, 9)			(~70%, 6 ↓, 12 ↑)			(~70%, 3 ↓, 15 ↑)		
	Med. C.	Tele.	Total	Med. C.	Tele.	Total	Med. C.	Tele.	Total
No. of patients, started (initiated) service	237	463	700	216	484	700	215	485	700
No. of closed cases	345	360	596	281	474	620	142	471	466
No. of patients, directed to Med. C. from Tele.	109	-	-	135	-	-	147	-	-
No. of active cases	1	103	104	70	10	80	220	14	-
physicians average-utilization	79%	98%	-	98% ↑	95% ↓	-	99% ↑	76% ↓	-

Total time spent in the center (min.)	24.2	98.0	-	87.6↑	62.3↓	-	155.1↑	33.6↓	-
---------------------------------------	------	------	---	-------	-------	---	--------	-------	---

**4.4 Scenario-4:** In this simulation scenario, the model was tested over 8 hours using the system parameters listed in Table 1. However, the examination focuses on the referral rate to the medical center from the telemedicine service.

The simulation results, summarized in Table 6, show the impact of different referral rates (30%, 20%, and 10%) from the telemedicine service to the medical center. The findings of this simulation experiment reveal that, given the system parameters in use, a higher referral rate to the medical center from the telemedicine service corresponds to an increased average physician utilization in the medical center, while simultaneously decreasing utilization at the telemedicine service. Consequently, this imbalance influences the overall time spent within the system. To alleviate the strain on physical medical centers, it is necessary to reduce the referral rate to the medical center from the telemedicine service and, simultaneously, increase the number of telemedicine physicians. In general, telemedicine services should be employed as much as possible to decrease the load on medical centers; however, the available resources must be considered.

Table 6. The simulation results, using different referral rate to the medical center from the telemedicine service.

KPI	Scenario 3								
	Referral rate to Med. C. from Tele.								
	30%			20% ↓			10% ↓		
	Med. C.	Tele.	Total	Med. C.	Tele.	Total	Med. C.	Tele.	Total
No. of patients, started (initiated) service	216	484	700	225	475	700	214	486	700
No. of closed cases	281	474	620	282	470	676	267	475	688
No. of patients, directed to Med. C. from Tele.	135	-	-	76	-	-	54	-	-
No. of active cases	70	10	80	19	5	24	1	11	12
physicians average-utilization	98%	95%	-	98%	94% ↓	-	92% ↓	95%	-
Total time spent in the center (min.)	87.5	62.3	-	61.4 ↓	52.4 ↓	-	44.4 ↓	77.5 ↑	-

## 5. Conclusions

Addressing the health challenges faced by pilgrims and visitors during Hajj and Umrah is crucial to ensure the safety and well-being of the millions who embark on these spiritual journeys each year. Creating and executing an integrated system with physical medical facilities and telemedicine services is one method for increasing the effectiveness and efficiency of medical care provided to pilgrims and Umrah visitors. Regardless of their locations, pilgrims could receive prompt, high-quality medical care through such a system. The key components of this integrated system include strategically located medical centers, accessible telemedicine services for remote consultations, and reliable communication networks.

Through the simulation model presented in this paper, we demonstrate the potential of such a system in improving the overall process flow and optimizing resources. By evaluating various simulation scenarios and measuring key performance indicators such as patient waiting times, cycle time, and physician utilization, it becomes evident that the proposed system can significantly enhance the delivery of healthcare services during these mass gatherings.

## 6. Recommendations

The following suggestions are made for the exploration and further research of various related issues:

- The integration and expansion of telemedicine services in healthcare systems are essential for providing efficient medical services to pilgrims and Umrah visitors. This can greatly maximize the benefits of healthcare services, improve patient outcomes, and contribute to the ongoing advancement of healthcare facilities.

- Utilizing simulation modeling tools, which involve strategic planning and optimization, is crucial for improving process flow in healthcare facilities. Simulation can help identify bottlenecks, inefficiencies, and areas for improvement. This allows for the testing of different scenarios and modifications without affecting real operations, streamlining processes, reducing wait times, optimizing resource utilization, and identifying the most efficient configurations.
- Establishing standardized protocols and guidelines for telemedicine services is essential to ensure consistency and quality of care. Additionally, defining and monitoring key performance indicators (KPIs) such as waiting times, resource utilization, and overall throughput is crucial for evaluating and improving system performance.
- The proposed model can be used as a future work for finding an optimal case for utilizing the available resources and at the same time providing a satisfactory medical services, which is considered an optimization problem.

## References

- Ahmad, J., et al. (2020). A Simulation Based Study for Managing Hospital Resources by Reducing Patient Waiting Time. IEEE Access, 8, 193523–193531. <https://doi.org/10.1109/access.2020.3032760>
- Alharbi, A., Alzuwaed, J., & Qasem, H. (2021). Evaluation of e-health (Seha) application: a cross-sectional study in Saudi Arabia. BMC Medical Informatics and Decision Making, 21(1). <https://doi.org/10.1186/s12911-021-01437-6>
- Aljohani, et al. (2022). E-government and logistical health services during Hajj season. Bulletin of the National Research Centre, 46(1). <https://doi.org/10.1186/s42269-022-00801-4>
- Almehmadi, M., & Alqahtani, J. S. (2023). Healthcare Research in Mass Religious Gatherings and Emergency Management: A Comprehensive Narrative Review. Healthcare, 11(2), 244. <https://doi.org/10.3390/healthcare11020244>
- Alrufaidi, K. M., et al. (2023). Prevalence of emergency cases among pilgrims presenting at King Abdulaziz International Airport Health Care Center at Hajj terminal, Jeddah, Saudi Arabia during Hajj season, 1440 H – 2019. Dialogues in Health, 2, 100099. <https://doi.org/10.1016/j.dialog.2023.100099>
- Bedoya-Valencia, L., & Kirac, E. (2016). Evaluating alternative resource allocation in an emergency department using discrete event simulation. SIMULATION, 92(12), 1041–1051. <https://doi.org/10.1177/0037549716673150>
- Darwinkel, M. (2017). Crowding at the Emergency Department of the Scheper Hospital Emmen [M.Sc. Thesis]. University of Twente, The Netherlands.
- Dergaa, I., et al. (2023). Telemedicine during the FIFA World Cup 2022: a potential tool to curtail the spread of infectious disease during times of pandemic. International Journal of Surgery, 109(2), 147. <https://doi.org/10.1097/JS9.0000000000000004>
- Kissell R. & Poserina J. (2017). Advanced Math and Statistics, Chapter 4 of the book: Optimal Sports Math, Statistics, and Fantasy, <https://doi.org/10.1016/B978-0-12-805163-4.00004-9>.
- Memish, Z. A., et al. (2012). Emergence of medicine for mass gatherings: lessons from the Hajj. The Lancet Infectious Diseases, 12(1), 56–65. [https://doi.org/10.1016/s1473-3099\(11\)70337-1](https://doi.org/10.1016/s1473-3099(11)70337-1)
- National Health Information Center (2023). Telehealth Application Guidelines., Saudi Health Council, Riyadh, In <https://nhic.gov.sa/standards/Telehealth/Telehealth-Application-Guidelines.pdf>.
- Saudi Vision 2030. <https://www.vision2030.gov.sa/media/cofh1nmf/vision-2030-overview.pdf>.
- Yezli, S., et al. (2022). Pattern of utilization, disease presentation, and medication prescribing and dispensing at 51 primary healthcare centers during the Hajj Mass Gathering. BMC Health Services Research, 22(1). doi:10.1186/s12913-022-07507-3





## Explainable Machine Learning for Predicting Foodborne Infections

Mashaal Al-Luhaybi<sup>1\*</sup>, and Amani Al-Luhaybi<sup>2</sup>

1-Computer Science Department, Jamoum University College, Umm Al-Qura University, 2-Clinical Nutrition Department, Armed Forces Hospital, King Abdul Aziz Naval base in Jubail.

\*Corresponding author: E-mail (mfluhaybi@uqu.edu.sa)

## استخدام التعلم الآلي القابل للتفسير للتنبؤ بالعدوى المنقولة بالغذاء

مشاعل اللهيبي<sup>1\*</sup>، أماني اللهيبي<sup>2</sup>

1- قسم علوم الحاسب الآلي، الكلية الجامعية بالجموم، جامعة أم القرى، 2- قسم التغذية العلاجية، مستشفى القوات المسلحة بقاعدة الملك عبد العزيز البحرية بالجبل.

### الملخص

تتضمن مستودعات بيانات الأمراض المنقولة بالغذاء على مسارات معقدة للبكتيريا والفيروسات وغيرها من البيانات المتعلقة بمكونات الأغذية الناقلة لتلك الأمراض. تصنيف هذه البيانات دون تقديم تفسيرات للقرارات التي تتخذها نماذج التصنيف الآلي إضافة في تسبب العديد من المعوقات التي تحد من تعميمها مستقبلاً بسبب التحيزات المحتملة في القرارات التي تتخذها خوارزميات التصنيف. لذلك، فإن فهم الارتباطات والتبعيات بين المتغيرات المتعلقة بالأمراض المنقولة بالغذاء، بما في ذلك المتغيرات التي يمكن أن تتأثر بالعوامل المسببة لمثل هذه الأنواع من الأغذية الملوثة وأنواع البكتيريا أو الفيروسات المسببة للعدوات الغذائية أمر بالغ الأهمية لتعزيز شفافية تنبؤات المصنفات الآلية. تقدم هذه الورقة البحثية نهجاً للتعلم الآلي القابل للتفسير، حيث تستخدم الشبكات البايزية (BNs) لنمذجة عدوى الأمراض المنقولة بالأغذية باستخدام النمذجة الرسومية. ولتحقيق ذلك، تم استخدام قاعدة البيانات الإلكترونية لتفشي الأمراض المنقولة بالغذاء (CDC database) لإيجاد العلاقات بين المتغيرات المرتبطة ببعض العدوات التي تنتقل عبر الأغذية، مثل النوروفيروس والسالمونيلا وغيرها باستخدام خوارزمية (EM).

تم استخدام هذه الخوارزمية لتحديد البنية الافتراضية للشبكة البايزية من خلال تقدير الحد الأقصى للاحتمالات (Maximum Likelihood) لتعزيز دقة النموذج التنبؤي. الهدف الرئيس لهذه الورقة العلمية هو تطوير نموذج تنبؤي ذكي يقدم تفسيراً منطقياً لتصنيف العدوات المنقولة عن طريق الأغذية مع التركيز على التصنيف الشفاف لمتغيرات هذه العدوات الغذائية لتحديد العوامل المسببة لها.

أظهرت النتائج فاعلية هذا النهج في التنبؤ بالعدوى المنقولة عبر الأغذية بنسب مرتفعة من الدقة تتراوح بين 80% و 88% للتنبؤ بعدوى النوروفيروس، والسالمونيلا، والإشريكية القولونية، والعطيفة، حيث وضحت النماذج الارتباطات والتبعيات بين متغيرات هذه العدوى مع تحديد موقعها الدقيق داخل هيكل الشبكة البايزية. كما أشارت تحليلات حساسية الشبكات البايزية إلى أن قدرات التمييز بين الحالات الإيجابية والسلبية للعدوات تجاوزت 77% لبعض العدوى، وحققت 90% لعدوى السالمونيلا والإشريكية القولونية. تسلط هذه النتائج الضوء على كفاءة نماذج الشبكات البايزية في التنبؤ بالعدوى الغذائية وتقديم رؤى واعدة للتطبيقات الصحية المستقبلية.

## Abstract

Foodborne disease repositories contain complex trajectories of bacteria, viruses, and other foodborne-related data. Classifying these trajectories without accompanying explanations for their decisions introduces several concerns, including the potential biases inherent in the decisions made by classification algorithms. Therefore, understanding the complex correlations and dependencies among attributes related to foodborne diseases such as those influenced by causative attributes (e.g., food types and specific types of bacteria or viruses), is crucial for enhancing the transparency of predictive classifiers. This research proposes an explainable machine learning approach utilizing Bayesian Networks (BNs) to explicitly model foodborne infections. The approach leverages the Foodborne Outbreak Online Database to capture the correlations among attributes associated with four of the most common foodborne infections, namely, Norovirus, *Salmonella enterica*, *Escherichia coli*, and *Campylobacter*, using the Expectation-Maximization (EM) algorithm. The EM algorithm is exploited to learn the parameters of the Bayesian structure by estimating the maximum likelihood for foodborne infection data. The primary technical objective of using the EM algorithm is to reduce uncertainty in the classification of foodborne diseases while emphasizing transparent classification of the infectious factors within the Bayesian model. Therefore, the explainable models showed promising validation results, with high accuracy in predicting Norovirus, *Salmonella*, *Escherichia coli*, and *Campylobacter*. Bayesian Network models consistently achieved accuracy results between 80% and 88%, identifying the correlations and dependencies between the foodborne attributes, targeting their precise location within the Bayesian network structure. Sensitivity and specificity analyses have also indicated discrimination capabilities exceeding 77%, reaching 90% for *Salmonella* and *Escherichia coli* infections. These findings highlight the efficiency of Bayesian Network models in predicting infections, offering insights for practical health applications and future refinements.

**Keywords:** Foodborne Infections, Explainable Machine Learning, Foodborne Prediction, Bayesian Networks (BNs)

## 1. Introduction

Foodborne diseases are illnesses caused by infections that enter the body through consumed food (Dodd C et al., 2017). Thus, contaminated foods and bacteria or viruses are often associated with these diseases. According to the World Health Organization (WHO), 600 million people worldwide are infected with foodborne illnesses each year, resulting in a total of 4.2 million deaths. In the U.S., the Center for Disease Control (CDC) reports 48 million cases of foodborne illness each year, resulting in 128,000 hospitalizations and 3,000 deaths (Oliver, 2019). China has also reported an increase in foodborne illnesses among surveillance of the population, with 294,000 reported cases in 2008 (Liu et al., 2018).

The spread of foodborne illnesses poses a serious threat to public health and the economy, prompting urgent investigation and prevention efforts. Therefore, researchers worldwide focus on monitoring, identifying, and predicting the outbreak of foodborne diseases. Identification and diagnosis methods for foodborne diseases involve molecular subtype analysis of pathogens using biochemical tests and statistical analysis or machine learning algorithms. The main cause of these diseases is the consumption of contaminated foods (Callan et al, 2011), emphasizing the importance of researching foodborne infections. However, the clinical features of diseases caused by different infections lack specificity, making intuitive identification challenging. Traditional laboratory testing methods are time-consuming (Mandal et al., 2011), leading to the proposal of rapid detection methods like nucleic acid, immune, and biosensor approaches. Despite advancements, these methods require specialized equipment, limiting their practical applications.

The low proportion of identified foodborne infections effect on disease diagnosis, affecting doctors to better investigate varied pathogen-caused diseases and potentially resulting in misdiagnosis. Additionally, the limited identification of causes of infection leads to unexplainable decisions, negatively impacting disease burden estimation and outbreak prediction. Addressing these challenges is crucial for effective foodborne infection management and prevention. Thus, machine learning and artificial intelligence have been applied widely to enhance the early prediction of foodborne diseases and their causes .

However, applying ML algorithms to classify foodborne data without providing an explanation rises several concerns, including issues related to bias and uncertainty in the decisions made by classifiers. This bias can be obtained from pre-existing biases in the datasets due to the sampling approach or historical decision-making procedures in the data collection process, leading to biased labels (Agurto et al., 2010). Therefore, there is a need to balance classification accuracy and explainability, as both significantly impact the decisions made during the implementation of AI models for predicting foodborne infections. A common approach to identify influential features in a decision is to uncover conditional independencies using Probabilistic Graphical Models (Pearl, 2011), such as implementing Bayesian Networks (BNs). This approach offers a transparent explanation of how a classification decision is reached, concentrating on the involvement of fundamental dependencies, including those related to food features such as raw meats or eggs.

In this research paper, four experiments have been compared to investigate the modeling of foodborne infections. The comparison involved examining the outcomes of four distinct experiments that focused on modeling foodborne infections applied the Foodborne Outbreak Online Database collected by the Centers for Disease Control and Prevention (CDC, 2023). The primary objective of these four experiments was to assess the effectiveness of a probabilistic graphical structure learning approach with Bayesian Networks (BNs) in predicting four prevalent foodborne infections: Norovirus, *Salmonella enterica*, *Escherichia coli*, and *Campylobacter*. Each individual experiment concentrated on a specific infection to analyze how foodborne-related features influenced the predictive performance for that particular infection. The explicit exploration of the impact of sensitive features was conducted by employing a Bayesian Network (BN) to facilitate a transparent classification decision. This involved investigating the BN structure to identify the Markov Blanket, revealing which features were utilized for classification purposes. These experiments have been explored therefore to show :

- The foodborne infection attributes dependencies and importance on computing the posterior probability of the predicted foodborne infection target class .
- The graphical explainable BN representation so that the relationships between the foodborne attributes are clearly stated in the Bayesian structure.
- The influence, strength and sensitivity analysis of each foodborne infection is based on the probability distribution of the nodes.

In this connection, the research is consisting of five sections. Firstly, it reviews existing literature on the utilization of machine learning algorithms for predicting foodborne diseases, and comparing these approaches with the methodology presented in this paper. Secondly, the paper introduces a Bayesian approach for detecting foodborne infections using the Foodborne Outbreak Online Database. This approach involves a probabilistic modeling strategy to uncover the connections between each foodborne infection and the food-related attributes associated with them, ensuring clear and transparent classification. Additionally, a sensitivity analysis approach for Bayesian networks is outlined to assess and emphasize the attributes that have the most significant impact on predicting the foodborne infections. The experimental

results section presents the graphical Bayesian network results, along with the outcomes of sensitivity analyses and the evaluation for predicting Norovirus, *Salmonella enterica*, *Escherichia coli*, and *Campylobacter* infections. Finally, the paper concludes by summarizing the achieved results and outlining future research directions.

## 2. Related Works

Machine learning (ML) has emerged as a valuable tool for various aspects of foodborne infection detection. Researchers have explored ML algorithms to identify high-risk locations, detect outbreaks, assess risks, and monitor contamination and antimicrobial resistance. In the context of adaptive inspections, machine learning applied to Twitter data has proven effective in identifying venues prone to foodborne illnesses, potentially preventing over 9,000 cases and 557 hospitalizations annually (Sadilek et al., 2016).

Moreover, the utilization of ML can enhance food safety by leveraging large datasets, enabling predictions related to antibiotic resistance, source attribution, and outbreak detection (Deng et al., 2021). Gradient boost decision tree models, a type of machine learning method, have demonstrated the ability to predict foodborne disease pathogens with an accuracy of around 69%, utilizing features such as space, time, and exposed food (Wang, 2021). Additionally, machine learning models contribute to predicting antimicrobial resistance in nontyphoidal salmonella (NTS) isolates from commercial chicken farms, providing improved surveillance and understanding of genomic mechanisms (Maguire et al., 2019). Machine learning algorithms are also employed to trace the origin of human *Campylobacter* infections by comparing DNA sequences from infected individuals, contaminated animals, and the environment (Arning et al., 2021). The primary focus of foodborne disease prediction lies in forecasting future trends related to specific aspects of the disease. Wang et al. (2018) tackled the reporting delay issue in the Foodborne Surveillance Database of the China National Center for Food Safety Risk Assessment (CFSA). They utilized a Bayesian hierarchical model to predict the true daily number of patients by considering the daily number of patients visited. In the realm of disease risk prediction, deep learning methods have been employed to anticipate short-term development trends in influenza-like diseases and foodborne diseases (Adhikari et al., 2019). Chen et al. (2019) introduced a regularization-based eXtreme Gradient Boosting (XGBoost) approach capable of predicting the trend of foodborne diseases.

While these predictive approaches have garnered significant attention, potential biases in decisions made by classification algorithms pose challenges. Understanding the intricate correlations and dependencies among attributes associated with foodborne diseases, particularly those influenced by causative factors such as food types and specific bacteria or viruses, is crucial for enhancing the transparency of predictive classifiers.

## 3. Methodology

### 3.1 Dataset Description

The proposed methodology in this paper was assessed using a real-world foodborne dataset. This dataset, collected by the Centers for Disease Control and Prevention (CDC, 2023), was mainly designed to enhance the accessibility of the Foodborne Disease Outbreak Surveillance System data for the general public and stakeholders. While the CDC utilizes more detailed information for their analyses of the causes and risk factors of foodborne disease outbreaks, our focus in this paper was to focus on the four most common foodborne infections: Norovirus, *Salmonella enterica*, *Escherichia coli*, and *Campylobacter*. Consequently, we specifically extracted data related to these four illnesses along with their corresponding foodborne-related information.

The extracted sample contains 1774 patient records between the years 2009 to 2012. Each record represents an individual patient data that includes details such as 'Location of Food Preparation,' 'Hospitalizations,' 'Deaths,' 'Contaminated Ingredient,' 'Raw Meat,' 'Cooked Meats,' 'Milk,' 'Seafood,' 'Eggs,' 'Sprouts,' 'Vegetables,' along with the class attributes '*Salmonella enterica*' for the Salmonella infection. The class attributes were binary; classified into 'Yes' if the patient had the specific foodborne infection or 'No' if the patient was not infected.

### 3.2 Bayesian Structure and Parameter Learning

#### 3.2.1 Structure Learning of the Bayesian Networks

As previously mentioned, this research paper introduces explainable machine learning (ML) models implemented for predicting foodborne infections such as *Salmonella enterica*, Norovirus as well as other infections through the utilization of a graphical probabilistic approach employing Bayesian Networks (BNs). In this context, the BN algorithm is applied to encode the probability distribution concerning foodborne-related features while also identifying potential correlations between these features and the occurrence of infections.

This is achieved by initially representing a directed acyclic graph (DAG) using the Bayesian Network (BN) algorithm, establishing conditional independence relationships between the features (Al-Luhaybi et al., 2019). The nodes within the DAG correspond to the foodborne features, and the links denote the conditional dependencies among these features in the graph. Consequently, the links are directed from parent nodes to child nodes of the food features, and the absence of identifying links calculates conditional independences. The expression of conditional independence between two educational features,  $x_1$  and  $x_2$ , given  $x_3$  signifies that  $x_1$  and  $x_2$  are independent once  $x_3$  is known, and this is encoded as:

$$p(x_1|x_2, x_3) = p(x_1|x_3)$$

Hence, a specific foodborne feature (node) within the BN is conditionally independent of all other foodborne features. This independence allows for the determination of the conditional probability distribution (CPD) for this particular feature. The computation of the CPD for each feature leads to the creation of the conditional probability table (CPT) for the Bayesian Network (BN), encoding the joint probability as:

$$p(x) = \prod_{i=1}^n p(x_i|pa_i)$$

In the Bayesian Network (BN),  $x_i$  represents a node, and  $pa_i$  denotes the parent nodes associated with this particular node, indicating features and nodes. The acquisition of the Bayesian network structure utilized GeNIe, a Java-based library for learning and modeling Bayesian networks (BNs), Dynamic Bayesian networks (DBNs), and influence diagrams (IDs). The Bayesian network structure learning process involved employing a Bayesian search method based on background knowledge from foodborne datasets. To facilitate the learning of the ordered BN structure, a Bayesian Search (BS) structure learning algorithm was utilized, specifically employing the CDC foodborne dataset to learn the highest posterior probability of the class feature.

The BS algorithm operates as a hill-climbing-based procedure, controlled by a scoring function, to generate a Directed Acyclic Graph (DAG) that determines a maximum score or probability, thereby defining the BN structure. This approach operates under the assumption that the prior probability of the BN structure is related to the data given the probability of such a structure (Heckerman et al., 1995).

### 3.2.2 Parameter Learning of the Bayesian Networks

Once the Directed Acyclic Graph (DAG) is generated, a crucial aspect in examining the Bayesian Network (BN) structure involves conducting Bayesian inference for probabilistic reasoning regarding foodborne features. The identification of Bayesian inference allows for the detection of the state of infection features as evidence, based on the CDC foodborne data. Each feature or node in the BN is associated with a state that depends on the states of other features. Inferring the BN using this approach facilitates the updating of evidence with new datasets to analyze the posterior probabilities of the features (Koller and Friedman, 2009). In the execution of Bayesian inference, the Bayes rule (Murphy et al., 2002) is utilized to determine the posterior probability of foodborne features based on the prior probability. For instance, to calculate the posterior probability for the class feature '*Salmonella enterica*'  $P(\text{Salmonella}|\text{Eggs})$ , given the prior probability for one of foodborne related features 'Eggs', the Bayes rule is calculated as:

$$P(\text{Salmonella}|\text{Eggs}) = \frac{P(\text{Eggs}|\text{Salmonella}) P(\text{Salmonella})}{P(\text{Eggs})}$$

Where  $P(\text{Salmonella})$  represents a prior probability (label of infection feature), and the  $P(\text{Eggs} | \text{Salmonella})$  is likelihood given the observed data of 'Eggs' and 'Salmonella' features. The determination of the joint distribution of the Bayesian Network (BN) based on the computed Bayes rule among the features allows for the inference of the probability distribution of a targeted feature, considering the CDC foodborne data for the other features in the dataset. Exact inference identification was applied to all food-related features to obtain the posterior probability in the BN for the class feature 'Salmonella' infection as in the previous equation, as well as for the other food features. Therefore, the primary objective of learning the Bayesian network is to ascertain the posterior distribution adapted to food-related features such as Eggs, Contaminated Ingredients, Raw meat, Seafood, and so on. This enables the identification of the states of all attributes and the precise infection. The parameters of the Bayesian model were acquired using the Expectation Maximization (EM) algorithm (Moon, 1996) with the CDC foodborne data. This algorithm was implemented to estimate the posterior distribution of the four foodborne infections investigated in this paper Norovirus, *Salmonella enterica*, *Escherichia coli*, and *Campylobacter*. The EM algorithm was utilized for learning the parameters of the BN to estimate the maximum likelihood for data (Moon, 1996). It iterates over a two-phase approach to fully learn the BN parameters, as follows:

**1. Expectation (E) Phase:** In this phase, the focus is on acquiring an expectation function to estimate log-likelihood based on the current parameters of the foodborne data set DS<sub>i</sub>. The foodborne features are  $\{x_1, x_2, \dots, x_n\}$ , the calculated expected  $x_1$  given a measure of  $Y_1$  from the current parameter estimate is determined as follows:

$$x_1^{[k+1]} = E [x_1 | Y_1, p^{[k]}]$$

**2- Maximization (M) phase:** The objective of this phase is to optimize the parameters of the log-likelihood that were expected in the previous stage. In the food context, the expected values of  $x_1^{[k+1]}$ , and  $x_2^{[k+1]}$  are replaced by  $x_3$  to determine the parameters of the log-likelihood. This requires measurement of outcomes of the log function of the yield with an equation of 0, expressed as follows:

$$0 = \frac{d}{dp} \log f (x_1^{[k+1]}, x_2^{[k+1]}, x_3 | p)$$

$$\rightarrow p^{[k+1]} = \frac{2x_2^{[k+1]} - x_3}{x_2^{[k+1]} + x_3}$$

The Bayesian Network (BN) parameters are acquired through an iterative process involving equations in the previous phases 1 and 2, repeated until convergence is achieved for all foodborne features and infections in the dataset.

### 3.3 Evaluation of the Explainable Bayesian Models

The explainable Bayesian models were developed using the CDC food-derived data from 2009 to 2012 as mentioned earlier, resulting in the following positive cases of infections investigated in this paper, as follow:

- Norovirus: 612 total cases, with only 159 positive cases.
- *Salmonella enterica*: 916 total cases, with only 415 positive cases.
- *Escherichia coli*: Total of 85 cases, with only 32 positive cases.
- *Campylobacter*: 161 total cases, including 40 positive cases.

To test the Bayesian models and avoid misclassification, a 10-fold cross-validation (CV) procedure was employed to ensure robust classifications. In this study method, the foodborne data for each infection was randomly divided into 10 equal groups. The first set (in Fold 1) served as the validation/testing dataset, while sets 2-10 were used to train Bayesian classifiers. This process was repeated ten times, with each iteration using a different validation set, ensuring comprehensive learning and testing of the classifiers.

The accuracy results from groups 1 to 10 were averaged to give a single estimate of accuracy. After each validation operation, the mean square error (MSE) was calculated for the validation data, resulting in MSE1, MSE2, ..., MSEK. The test error of the classifier was calculated by averaging these mean square errors (James et al., 2013).

$$CV_{(K)} = \frac{1}{K} \sum_{i=1}^K MSE_i$$

Therefore, in this exploratory study, the 10-fold cross-validation (CV) method, as resampling method (James et al., 2013) was used to increase the skill of the Bayesian predictive classifier and to improve the reliability of accuracy with results showing ways to identify whether each infection for instance *Salmonella* is positive/yes or negative/no.

To evaluate the efficiency of the Bayesian infection classifiers, three performance evaluation metrics were employed for each foodborne infection. These evaluation measures, namely model accuracy (ACC), sensitivity (SN), and specificity (SP), are widely utilized in the literature to evaluate classifier performance (Labatut and Cherifi, 2012). They are defined as follows:

$$ACC = \frac{(TP + FN)}{(TN + TP + FN + FP)}$$

$$SN = \frac{TP}{(TP + FN)}$$

$$SP = \frac{TN}{(TN + FP)}$$

Here, TP, FP, TN, and FN denote True Positive, False Positive, True Negative, and False Negative cases, respectively. For instance, in the classification of *Salmonella* infection, representing the positive/yes class, TP signifies the number of correctly classified patients by the classifier who were indeed in the positive class. FP represents the number of positively tested patients misclassified by the classifier but were originally in this class (as positive cases/yes label).

TN signifies the number of patients in the other classes that were correctly classified, while FN indicates the number of misclassified patients from the other classes who were originally labeled from these classes.

#### 4. Experimental Results and Discussion

##### 4.1 PC Results

The Parent-Child (PC) algorithm played a crucial role in discerning potential causal links between foodborne attributes and infections within the CDC dataset. Specifically, this algorithm aimed to show parent-child relationships in a Bayesian network through the examination of conditional independence tests. In the Bayesian network represented in Figure 1, nodes represent foodborne-related attributes, involving 'Raw Meat', 'Cooked Meats', 'Milk', 'Seafood', 'Eggs', 'Sprouts', and 'Vegetables'. The directed edges between nodes signify probabilistic dependencies or causal relationships.

The PC algorithm facilitated the explanation of these relationships by iteratively testing and adjusting edges based on statistical independence tests. Thus, the Parent-Child algorithm proves indispensable for exploring and comprehending the causal relationships and dependencies among foodborne attributes in a dataset, ultimately contributing to the construction of precise Bayesian network models. In Figure 1, three direct relationships with the predicted class 'Salmonella' are apparent: 'Eggs', 'Location of Food Preparation,' and 'Contaminated Ingredient.' These relationships can be further examined using the EM algorithm to identify the attributes that have been identified as the most influential ones and have a direct impact on predicting Salmonella.

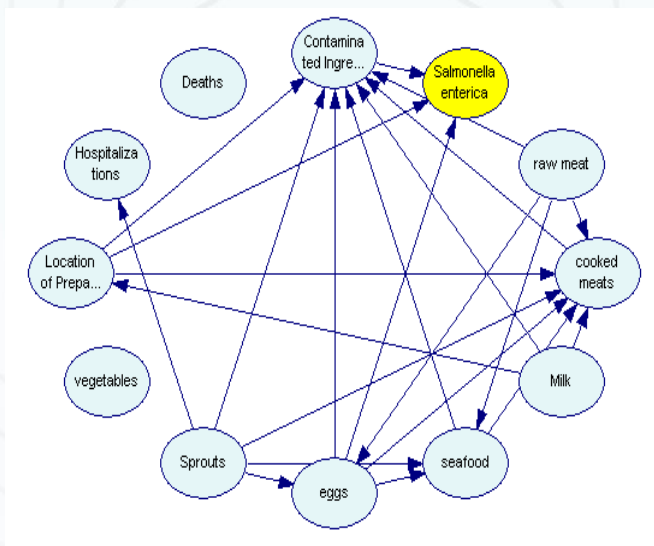


Figure1. Relationships between the 'Salmonella' infection and food related attributes by applying the PC algorithm.

##### 4.2 Influence Strength Analysis of the Bayesian Networks

The Bayesian network (BN) developed from foodborne *Salmonella* illness data is illustrated in Figure 2. This network exploits the correlations among foodborne features to detect the 'Salmonella' class and the strength of influence identified among these features. The influence strength is derived from conditional probability tables (CPT) of the child nodes, essentially obtained by assessing the distances between the probability distributions of the child nodes and the parent nodes.



The weights and colors of the arcs in Figure. 2 indicate the strength of the influence on the parent and child nodes. Therefore, the highlighted 'blue' arcs indicate the strongest influence in the network. Items identified as "most important parameters" such as 'Contaminated Ingredient', 'eggs', and 'raw meat', exhibit a direct effect on the '*Salmonella*' class. In addition, the Bayesian network (BN) model is significant as it provides insight into link-strength analysis of parameters. The red nodes represent important parameters for estimating the posterior probability distribution of the '*Salmonella*' class, allowing a clear identification of important dependencies and their relationship to the class node.

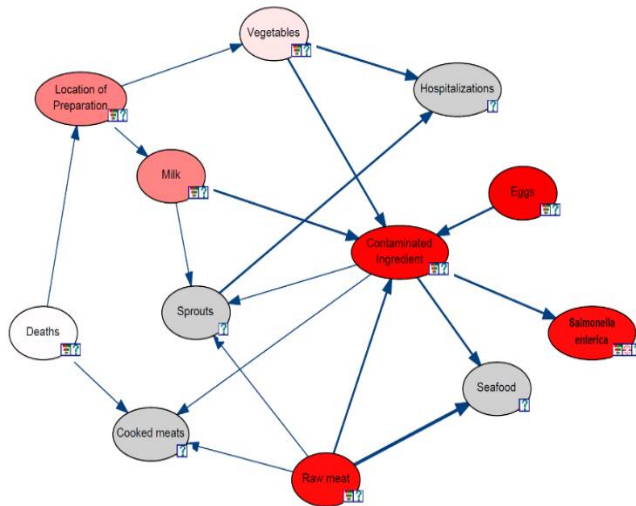


Figure 2. Influence strength and sensitivity analysis of the BN based on the marginal probability distribution of the parent and child nodes for predicting '*Salmonella*' infection.

From the BN in Figure 2, it is clear that the '*Salmonella*' class node is affected by the 'Contaminated Ingredients' node, highlighting the direct impact of this feature on the prediction. In contrast, gray and transparent nodes do not have parameters to calculate the posterior probability of the '*Salmonella*' class node. Within this BN, it is apparent that most grey-colored nodes involve hospitalization and some food-related features such as cooked meat, seafood, and sprouts, which do not directly contribute to the overall prediction of this specific infection (additional information on the exploited BNs of the other infections in the Appendix section).

Moreover, Table 1 presents the influence strength values calculated between parent and child nodes for the identification of '*Salmonella*' using the Euclidean distance with three different measurement approaches: Average, Maximum, and Weighted. Subsequently, a visual representation using the weighted method (as illustrated in the arcs in Figure. 2) was selected to show the weighted strength between parent nodes and child nodes based on a marginal probability distribution. In detail, the bold 'Weighted' values in Table 1 indicate the highest influence detected between parent and child nodes in the Bayesian Network.

For instance, the parent node 'Contaminated Ingredient' detects the highest influence strength value of 0.355719 in detecting the posterior probability of the child node '*Salmonella enterica*' infection. Whereas 'Contaminated Ingredient' has been directly influenced by the posterior probability of Eggs, Milk, Raw meat and vegetables attributes.

Table 1. Influence strength values of the correlations between all parent and nodes for predicting 'Salmonella' based on the Euclidean Distance Influence of the Average, Maximum and Weighted Distance.

Parent Node	Child Node	Average	Maximum	Weighted
Contaminated Ingredient	Sprouts	0.107976	0.933903	0.107976
<b>Contaminated Ingredient</b>	<b>Salmonella enterica</b>	0.355719	0.884249	<b>0.355719</b>
Contaminated Ingredient	Cooked meat	0.124194	0.984987	0.124194
Contaminated Ingredient	Seafood	0.244743	0.979736	0.244743
Deaths	Location of Preparation	0.090894	0.090894	0.090894
Deaths	Cooked meat	0.178006	0.488889	0.178006
<b>Eggs</b>	<b>Contaminated Ingredient</b>	0.264722	0.708837	<b>0.264722</b>
Location of Preparation	Milk	0.178288	0.733402	0.178288
Location of Preparation	Vegetables	0.0819238	0.246269	0.0819238
<b>Milk</b>	<b>Contaminated Ingredient</b>	0.265901	0.655059	<b>0.265901</b>
Milk	Sprouts	0.191972	0.496403	0.191972
<b>Raw meat</b>	<b>Contaminated Ingredient</b>	0.264111	0.634777	<b>0.264111</b>
Raw meat	Sprouts	0.167107	0.496403	0.167107
Raw meat	Cooked meat	0.194135	0.926389	0.194135
<b>Raw meat</b>	<b>Seafood</b>	0.301136	0.816667	<b>0.301136</b>
Sprouts	Hospitalizations	0.255329	0.333333	0.255329
<b>Vegetables</b>	<b>Contaminated Ingredient</b>	0.267005	0.609463	<b>0.267005</b>
Vegetables	Hospitalizations	0.240177	0.318182	0.240177

#### 4.3 Validation Results of the Explainable Bayesian Models

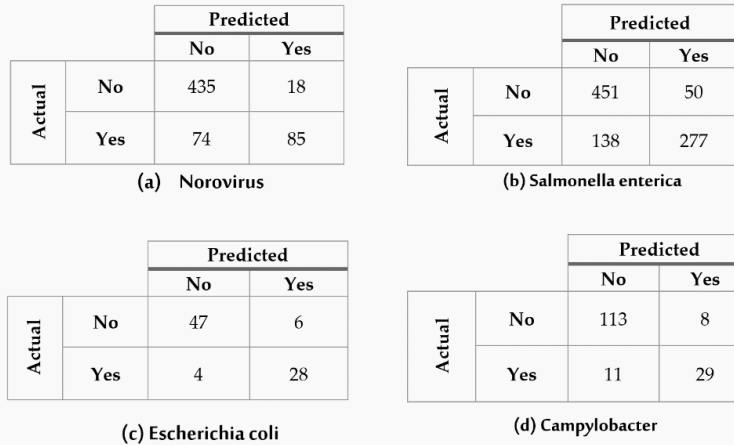
The evaluation of Bayesian Networks produced promising validation results for predicting the foodborne infections, as reflected in the confusion matrices, prediction outcomes, and Receiver Operating Characteristic (ROC) curves.

The confusion matrices in Figure 3 illustrate the number of correctly predicted positive/yes and negative/no instances in predicting the four infections explored in this paper using foodborne data.

To illustrate, in the confusion matrix represented in (b) for predicting *Salmonella*, 451 negative cases were accurately predicted out of a total of 501. Similarly, within the same matrix, 277 negative cases were classified correctly out of a total of 415, highlighting a very satisfactory overall performance of the Bayesian classifier. Additionally, it is apparent that all the confusion matrices yield high classification results, particularly for classifying the positive cases of each infection, as they were classified and labeled correctly without encountering misclassification issues due to the low number of cases.

To assess the effectiveness of the Bayesian Network (BN) explainable models, accuracy, sensitivity, and precision were employed as metrics to predict the four class attributes: Norovirus, *Salmonella enterica*, *Escherichia coli*, and *Campylobacter*. The results presented in Table 2 demonstrate that all models consistently achieve high accuracy rates ranging from 80% to 88% in predicting foodborne infections.

This selection of metrics ensures a fair comparison, allowing an investigation into the significance of the proposed model when implementing Bayesian Networks. In simpler terms, these measures serve as constraints to evaluate the mutual information between foodborne related attributes and the overall performance within this network.



**Figure 3.** The confusion matrices result of the four experiments for the Bayesian explainable models for predicting (a) Norovirus, (b) *Salmonella enterica*, (c) *Escherichia coli* and (d) *Campylobacter* foodborne infections.

**Table 2.** Prediction results obtained by the learned ‘BNs’ datasets for the foodborne infections.

Foodborne Infections	Class Domain Values	Class Accuracy	BN overall Accuracy	Sensitivity	Precision
Norovirus	Yes (Positive)	0.53	0.85	0.96	0.85
	No (Negative)	0.96			
<i>Salmonella enterica</i>	Yes	0.67	0.80	0.90	0.77
	No	0.90			
<i>Escherichia coli</i>	Yes	0.88	0.88	0.89	0.92
	No	0.89			
<i>Campylobacter</i>	Yes	0.73	0.88	0.93	0.91
	No	0.93			

The evaluation of four Bayesian network models for predicting foodborne infections produced distinguished performance metrics across various infections. The Norovirus model obtain exceptional sensitivity (0.96) and precision (0.85), showcasing its effectiveness in accurately identifying true positive cases of this infection. The *Salmonella enterica* model demonstrated a robust sensitivity of 0.90, capturing a significant portion of positive instances, but its precision (0.77) indicated a relatively lower accuracy in positive predictions compared to the Norovirus model. The *Escherichia coli* model achieved a well-balanced performance, boasting a sensitivity of 0.89 and precision of 0.92, showcasing its proficiency in both identifying and accurately classifying positive instances. Lastly, the *Campylobacter* model excelled with a high sensitivity of 0.93 and commendable precision of 0.91, emphasizing its effectiveness in capturing true positive cases and providing accurate positive predictions. Collectively, these results highlight the strengths of each Bayesian network model in predicting specific foodborne infections, offering valuable insights for further refinement and real-world applications.

Moreover, we performed sensitivity and specificity analyses on predicted positive/yes and negative/no infections from food sources in order to assess the effectiveness of the foodborne infection Bayesian prediction models. To this end, we used the receiver operating characteristic curve (ROC) and visualized the area under the curve (AUC), as depicted in Figure 4. These two-performance metrics were used due to the binary classes of the predictive models. The ROC curves in Figure 4, illustrate that the positive states for the four predicted infections exhibit very high sensitivity and specificity,

both exceeding 77% and some infections are reaching 90%. This indicates a very good discrimination and an overall accurate prediction based on the foodborne CDC data.

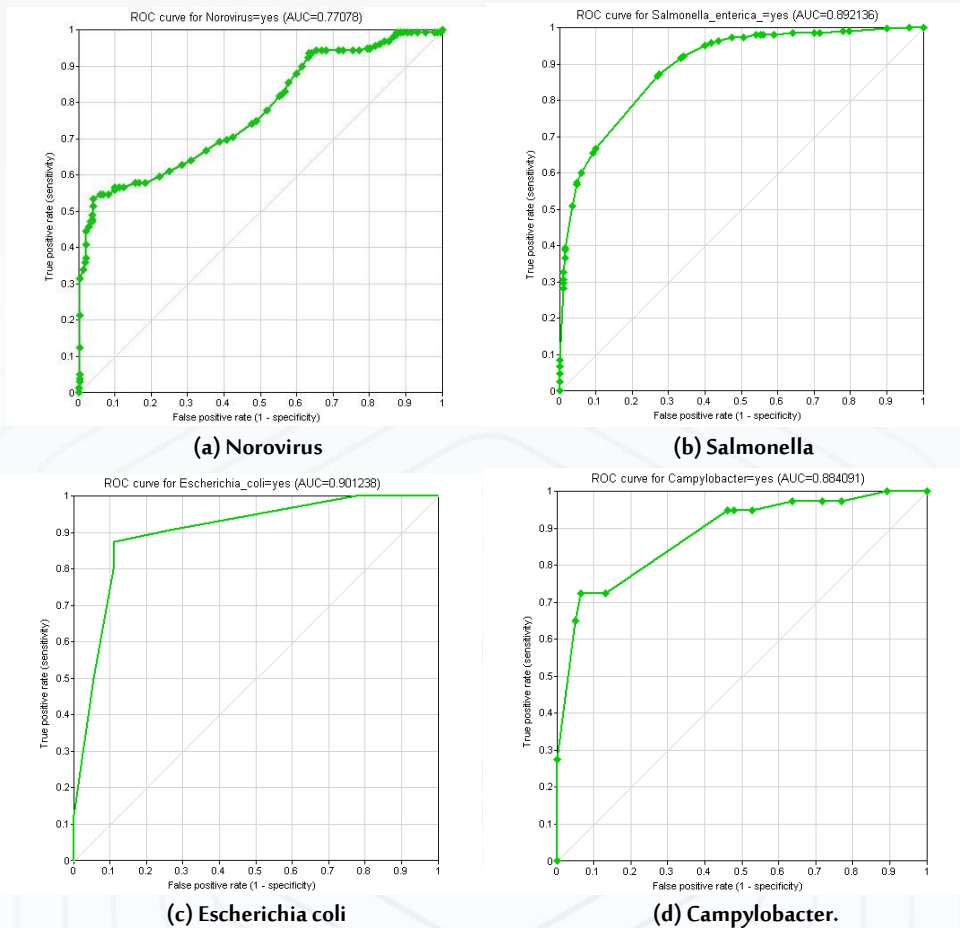


Figure 4. ROC curves of the infections prediction performance using the CDC foodborne data. It represents the ROC curves for the positive/yes states for each infection, these being: (a) Norovirus, (b) *Salmonella*, (c) *Escherichia coli* and (d) *Campylobacter* infections.

## 5. Conclusions

This research paper explores the crucial domain of foodborne infections, unveiling their prevalence, impact, and the pressing requirement for robust prediction and management strategies. The substantial global data provided by entities like the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) underscores the substantial threat posed by foodborne diseases to public health and the economy. While the investigation of Machine Learning (ML) algorithms for predicting foodborne infections holds promise, it also introduces challenges related to bias and decision-making uncertainty.

The paper introduces a Bayesian explainable approach, providing probabilistic graphical models, specifically Bayesian Networks (BNs), to predict prevalent foodborne infections: *Norovirus*, *Salmonella enterica*, *Escherichia coli*, and *Campylobacter*. The experiments conducted provide comprehensive insights into the dependencies of foodborne

attributes and emphasize the importance of explainability in classification decisions. The research not only presents the results of Bayesian models' accuracy, sensitivity, and precision but also investigates into the underlying causal relationships among food-related attributes using the Parent-Child (PC) algorithm.

Through sensitivity analysis, the experiments explain the strength of influence and relationships among foodborne related attributes, highlighting key attributes that significantly impact the prediction of foodborne infections. The application of the Bayesian models to real-world data 'CDC data' produces promising results, with high overall accuracy rates reaching 88% for some infections. The Bayesian models have also exhibited distinguished performance metrics across various infections, with Norovirus model showing exceptional sensitivity (0.96) and precision (0.85). *Salmonella* model and other infections models achieving well-balanced performance over (0.90) sensitivity and precision. Additionally, sensitivity and specificity analyses were conducted on predicted positive and negative infection cases using ROC curves, illustrating very high sensitivity and specificity exceeding 77% and reaching 90% for some infections (*Salmonella* and *Escherichia coli*). These results indicate excellent discrimination and overall accurate predictions based on foodborne CDC data. Comparing these results with existing literature highlight the significance of the proposed methodology, emphasizing the transparency and interpretability offered by the Bayesian approach. These results emphasize the strengths of Bayesian network modeling in explaining and predicting foodborne infections, providing valuable insights for further refinement in other real-world health applications. Furthermore, the results contribute to the ongoing efforts in foodborne diseases prediction by introducing a transparent and effective predictive modeling approach. The findings not only advance our understanding of the complex relationships among foodborne attributes but also provide valuable insights for future health research directions in the domain of foodborne infection prediction and management.

## References

- Adhikari, B., Xu, X., Ramakrishnan, N., & Prakash, B. A. (2019). Epideep: Exploiting embeddings for epidemic forecasting. In Proceedings of the 25th ACM SIGKDD international conference on knowledge discovery & data mining (pp. 577-586)
- Agurto, C., Murray, V., Barriga, E., Murillo, S., Pattichis, M., Davis, H., ... & Soliz, P. (2010). Multiscale AM-FM methods for diabetic retinopathy lesion detection. *IEEE transactions on medical imaging*, 29(2), 502-512.
- Al-Luhaybi, M., Yousefi, L., Swift, S., Counsell, S., & Tucker, A. (2019). Predicting academic performance: a bootstrapping approach for learning dynamic bayesian networks. In *Artificial Intelligence in Education: 20th International Conference, AIED 2019, Chicago, IL, USA, June 25-29, 2019, Proceedings, Part I 20* (pp. 26-36). Springer International Publishing.
- Arning, N., Sheppard, S. K., Bayliss, S., Clifton, D. A., & Wilson, D. J. (2021). Machine learning to predict the source of campylobacteriosis using whole genome data. *PLoS genetics*, 17(10), <https://doi.org/10.1371/journal.pgen.1009436>.
- CDC. (n.d.-b). Centers for Disease Control and Prevention. Retrieved November 11, 2023, from <https://www.cdc.gov/foodsafety/outbreaks/index.html>
- Chen, S., Xu, J., Chen, L., Zhang, X., Zhang, L., & Li, J. (2019). A regularization-based eXtreme Gradient Boosting approach in foodborne disease trend forecasting. In *MEDINFO 2019: Health and Wellbeing e-Networks for All* (pp. 930-934). IOS Press.
- Deng, X., Cao, S., & Horn, A. L. (2021). Emerging applications of machine learning in food safety. *Annual Review of Food Science and Technology*, 12, 513-538.
- Dodd, C. E., Aldsworth, T. G., & Stein, R. A. (Eds.). (2017). *Foodborne diseases*. Academic Press.
- Friedman, N., Goldszmidt, M., & Wyner, A. (2013). Data analysis with Bayesian networks: A bootstrap approach. arXiv preprint arXiv:1301.6695.

- Heckerman, D., Geiger, D., & Chickering, D. M. (1995). Learning Bayesian networks: The combination of knowledge and statistical data. *Machine learning*, 20, 197-243.
- James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). *An introduction to statistical learning* (Vol. 112, p. 18). New York: Springer.
- Koller, D., & Friedman, N. (2009). *Probabilistic graphical models: principles and techniques*. MIT press.
- Labatut, V., & Cherifi, H. (2012). Accuracy measures for the comparison of classifiers. *arXiv preprint arXiv:1207.3790*.
- Liu, J., Bai, L., Li, W., Han, H., Fu, P., Ma, X., ... & Guo, Y. (2018). Trends of foodborne diseases in China: lessons from laboratory-based surveillance since 2011. *Frontiers of medicine*, 12, 48-57.
- Maguire, F., Rehman, M. A., Carrillo, C., Diarra, M. S., & Beiko, R. G. (2019). Identification of primary antimicrobial resistance drivers in agricultural nontyphoidal *Salmonella enterica* serovars by using machine learning. *Msystems*, 4(4), 10-1128.
- Mandal, P. K., Biswas, A. K., Choi, K., & Pal, U. K. (2011). Methods for rapid detection of foodborne pathogens: an overview. *American Journal of Food Technology*, 6(2), 87-102.
- Moon, T. K. (1996). The expectation-maximization algorithm. *IEEE Signal processing magazine*, 13(6), 47-60.
- Murphy, K. P. (2002). *Dynamic bayesian networks: representation, inference and learning*. University of California, Berkeley.
- Oliver, S. P. (2019). Foodborne pathogens and disease special issue on the national and international PulseNet network. *Foodborne pathogens and disease*, 16(7), 439-440.
- Sadilek, A., Kautz, H., DiPrete, L., Labus, B., Portman, E., Teitel, J., & Silenzio, V. (2017). Deploying nEmesis: Preventing foodborne illness by data mining social media. *Ai Magazine*, 38(1), 37-48.
- Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M. A., Roy, S. L., ... & Griffin, P. M. (2011). Foodborne illness acquired in the United States—major pathogens. *Emerging infectious diseases*, 17(1), 7.
- Wang, H., Cui, W., Guo, Y., Du, Y., & Zhou, Y. (2021). Machine learning prediction of foodborne disease pathogens: Algorithm development and validation study. *JMIR medical informatics*, 9(1), e24924.
- Wang, X., Zhou, M., Jia, J., Geng, Z., & Xiao, G. (2018). A Bayesian approach to real-time monitoring and forecasting of Chinese foodborne diseases. *International journal of environmental research and public health*, 15(8), 1740.

## Appendix

The strength of influence observed between the foodborne attributes and the class node, representing other foodborne infections, is illustrated in Figures A.1, A.2, and A.3. These visualizations were generated from the conditional probability tables (CPT) of the child nodes within the Bayesian Networks (BNs) by employing distance measures between the probability distributions of the child nodes and the parent nodes. In these figures, the influence strength is visually represented through the thickness and color of the arcs, with strong influences highlighted in 'blue'.

The BNs also serve as a platform for conducting sensitivity analysis on significant parameters affecting the class node. For instance, in Figure A.1, red nodes encompass crucial parameters for computing the posterior probability distribution of the 'Norovirus' infection class, while grey nodes lack any parameters utilized in the learning process for this class. Consequently, these visualizations allow for a clear distinction of important dependencies and their correlations with the class node.

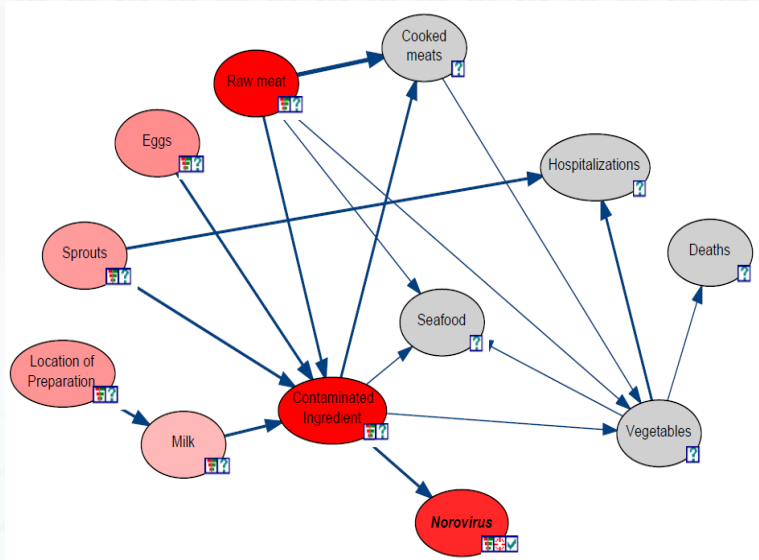


Figure A.1 Influence strength and sensitivity analysis of the BN based on the marginal probability distribution of the parent and child nodes for predicting 'Norovirus' infection.

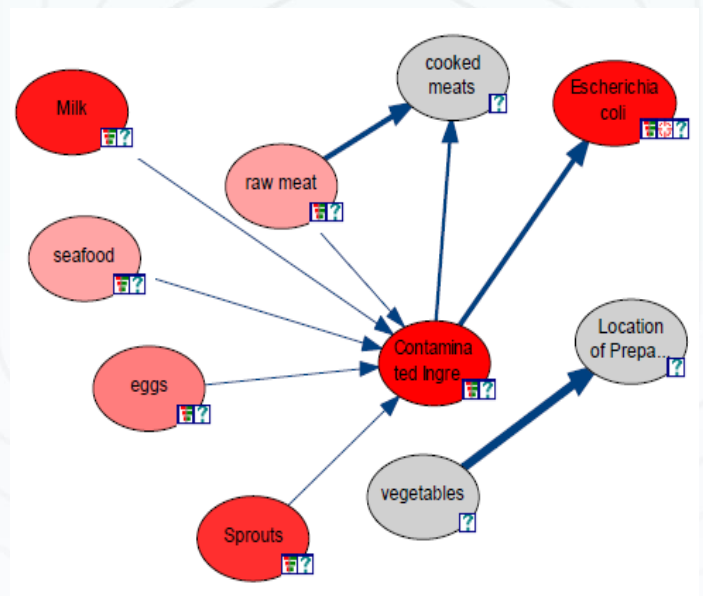


Figure A.2 Influence strength and sensitivity analysis of the BN based on the marginal probability distribution of the parent and child nodes for predicting 'Escherichia Coli' infection.

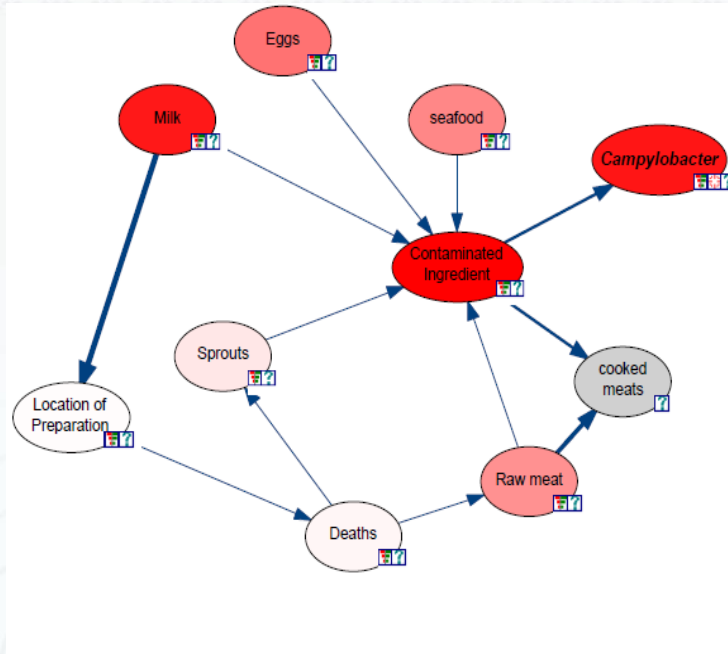


Figure A.3 Influence strength and sensitivity analysis of the BN based on the marginal probability distribution of the parent and child nodes for predicting 'Campylobacter' infection.





## Technological Transformations in Combating Medically Important Arthropods during the Hajj and Umrah Seasons

Salwa Oshiba<sup>1</sup>, and Ashraf Elwy\*<sup>2</sup>

1- Department of Medical Parasitology, Faculty of Medicine, Menoufia University, Shebin El-Kom, Egypt, 2- Department of  
Mechanical Engineering, College of Engineering, Taif University, Saudi Arabia.

\*Corresponding author: E-mail (ashrafbalabel@yahoo.com)

## التحولات التكنولوجية في مكافحة المفصليات ذات الأهمية الطبية خلال موسمي الحج والعمرة

سلوي عشيبة<sup>1</sup>، أشرف علوي\*<sup>2</sup>

1- قسم الطفيليات الطبية – كلية الطب – جامعة المنوفية - جمهورية مصر العربية، 2- قسم الهندسة الميكانيكية-كلية الهندسة-جامعة الطائف – المملكة العربية  
السعودية.

### الملخص

يجذب موسما الحج والعمرة ملايين الحجاج من جميع أنحاء العالم إلى مدينتي مكة والمدينة المقدستين في المملكة العربية السعودية، مما يخلق تحدياً فريداً لمسؤولي الصحة العامة في إدارة انتشار الأمراض، وخاصة تلك التي تنتقل عن طريق المفصليات ذات الأهمية الطبية. يمكن للمفصليات ذات الأهمية الطبية، بما في ذلك البعوض والقراد والبراغيث والذباب والقمل والبعث والبق، أن تنقل أمراضاً مثل الملاريا وحى الضنك ومرض لايم وغيرها، مما يشكل خطراً صحياً كبيراً على الحجاج خلال مواسم الحج والعمرة. إن التدفق الكبير للأشخاص من بلدان مختلفة، وغالباً ما يكون لديهم مستويات متفاوتة من المناعة ضد هذه الأمراض، يزيد من خطر انتقال العدوى. في الآونة الأخيرة، مكنت التطورات التكنولوجية السلطات من تنفيذ تدابير مستهدفة وفعالة للحد من انتشار المفصليات ذات الأهمية الطبية خلال هذه المواسم. وتتراوح هذه التدابير من استخدام أنظمة متطورة لرصد الطقس للتنبؤ بتواجد المفصليات، إلى نشر الطائرات بدون طيار والروبوتات لمكافحة الآفات، وحتى استخدام تقنيات التعديل الوراثي لتقليل قدرة المفصليات على نقل الأمراض. يمكن لنظم المعلومات الجغرافية وشبكات الأعصاب الإصطناعية المساهمة بشكل كبير في حل مشكلة المفصليات وقدرتها على نقل الأمراض. تتناول هذه الورقة التحولات التكنولوجية المختلفة المقترح تنفيذها لمكافحة المفصليات ذات الأهمية الطبية خلال مواسم الحج والعمرة، وفعاليتها، والتحديات، وطرق المكافحة المستقبلية التي تبقى في ضمان صحة وسلامة حجاج بيت الله الحرام خلال هذه المناسبات الدينية.

### Abstract

The Hajj and Umrah seasons attract millions of pilgrims from around the world to the holy cities of Mecca and Medina in Saudi Arabia, creating a unique challenge for public health officials in managing the spread of diseases, particularly those transmitted by medically important arthropods. Medically important arthropods, including mosquitoes, ticks, fleas, flies, lice, mites, and bugs can transmit diseases such as malaria, dengue, and Lyme disease, among others, posing a significant health risk to pilgrims during the Hajj and Umrah seasons. The large influx of people from different countries,

often with varying levels of immunity to these diseases, increases the risk of transmission. Recently, technological advancements have enabled authorities to implement targeted and effective measures to reduce the prevalence of medically important arthropods during these seasons. These measures range from the use of sophisticated weather monitoring systems to predict the occurrence of arthropods, to the deployment of drones and robots for pest control, and even the use of genetic modification techniques to reduce the vector capacity of the arthropods. GIS and ANN can also contribute significantly to solving this issue (arthropods and their potential for disease transmission). In this review article, various technological transformations that could be implemented to combat medically important arthropods during the Hajj and Umrah seasons are discussed, their effectiveness, the challenges, and the future combating methods that remain in ensuring the health and safety of pilgrims during these important religious events.

**Keywords:** Hajj and Umrah Seasons, Medically Important Arthropods, Technological Transformations, Public Health, Disease Control.

## 1. Introduction

Medically important arthropods are a group of insects and arachnids that have the potential to transmit diseases or cause harm to human health. Some common examples include mosquitoes, flies, fleas, ticks, lice, mites, and bugs. Medically important arthropods can have a significant impact on public health by transmitting diseases and causing skin irritation, rashes, or allergic reactions. Vector-borne diseases can cause severe illness and even death in some cases. Examples of such diseases include malaria, dengue, Lyme disease, and Zika virus. These diseases can spread rapidly, particularly in areas with high population density (Robert and Debboun, 2020). Effective control strategies can assist in minimizing the risk of disease transmission. The first focus of management strategies was on physically getting rid of insects and arachnids, such as by using screens, nets, and repellents to lessen human contact. The widespread use of pesticides, particularly DDT, was the main strategy for controlling mosquitoes. However, worries about these compounds' effects on the environment and human health prompted a shift towards more focused and environmentally controlled strategies. Today, biological control methods, genetic modification of insect populations, development of vaccines and technological transformation methods are approaches used to control medically significant arthropods (Niang et al., 2018).

## 2. Methodology (Materials and methods)

### 2.1 Current control methods

**2.1.1 Quarantine procedures:** Quarantine measures can involve the inspection of goods and people entering a country or region to ensure that they are not carrying infected arthropods. One common example of quarantine procedures is the inspection of cargo containers and ships for the presence of insects and arachnids. These inspections can help prevent the accidental transport of arthropods from one country to another. Similarly, travelers arriving from areas with a high prevalence of vector-borne diseases may be subject to screening and health checks (Dubey et al., 2021).

**2.1.2 Inspections:** They involve the examination of goods, cargo, and people for the presence of these organisms to prevent their spread to new areas. Inspections can be carried out at various points, including at ports of entry, airports, and border crossings. Trained personnel use a range of tools and techniques to detect infestations, such as visual inspections, the use of traps, and the examination of cargo manifests. If an infestation is detected, quarantine procedures and pest management methods may be employed to eliminate the arthropods and prevent their spread.

### 2.1.3 Pest management techniques (Barzman et al., 2016)

**2.1.3.1 Biological control:** Predators such as dragonflies, birds, or fish that consume pests can help to reduce their populations. Also, parasitic wasps, for example, can be used to control pest populations by laying their eggs in the bodies of the pests. The wasp larvae then consume the pest from the inside, eventually killing it. In addition, certain types of bacteria, viruses, or fungi can be used to infect and kill pests. For example, the *Bacterium Bacillus thuringiensis* (Bt) can be used to control mosquito populations by infecting and killing the larvae. Some biocontrol agents, such as nematodes or fungi, are specifically developed to target specific pest species.

**2.1.3.2 Chemical control (Roubos et al., 2019 & WHO, 2020):** Insecticides such as permethrin or DEET, can be applied to clothing, bed nets, or directly to the skin to help repel or kill arthropods. Larvicides such as methoprene or methionine, are used to control pest populations by targeting the larval stage. These chemicals are often applied to water sources, such as ponds or standing water, where mosquitoes or other pests lay their eggs. Also, adulticides such as malathion or pyrethrins, are used to kill adult arthropods. It is important to use pesticides responsibly and according to label instructions. Overuse or misuse of pesticides can lead to the development of pesticide resistance, as well as potential negative impacts on non-target species and the environment.

**2.1.3.3 Environmental management (Ghiglieno et al., 2021):** Cultural control involves modifying the environment or human behavior to reduce the presence of medically important arthropods. Removing standing water, clearing vegetation, and keeping lawns trimmed can help to reduce arthropod habitats and breeding sites. Proper disposal of waste materials, such as garbage, can help to reduce the availability of food sources for pests. Also, ensuring that buildings are properly designed and maintained, with screens on windows, doors, and vents can help to keep pests out and reduce the risk of disease transmission.

**2.1.3.4. Behavioral changes:** Encouraging behaviors that reduce exposure to pests, such as wearing protective clothing or avoiding peak activity times, can help to reduce the risk of disease transmission. Mechanical control measures involve the use of physical barriers or devices to manage populations of medically important arthropods. Screens, netting, or other physical barriers can be used to keep pests out of homes, buildings, or specific areas. Various types of traps, such as light traps, CO<sub>2</sub> traps, or sticky traps, can be used to catch and kill pests. These traps can be effective at minimizing the risk of disease transmission. Specialized vacuums, such as those used for bed bug control, can be used to physically remove pests from an area. Also, in some cases, heating or cooling techniques can be used to control pest populations. For example, high temperatures can be used to kill bed bugs or their eggs, while freezing temperatures can be used to kill mosquito eggs or larvae.

**2.1.3.5 Development of Vaccination:** For example, due to the hematophagous habits of the ticks, they can consume significant amounts of blood, causing immunosuppressive effects. In addition, ticks are the major transmitters of pathogens, including viruses, bacteria, and protozoa. Tick infestations are controlled with acaricides; however, disadvantages of their use including the growing resistance of ticks to ixodicides, the negative impact on human and animal health, and the ecological damage on the environment force the use of new sustainable alternatives such as immune control through vaccination (Van Oosterwijk and Wikel, 2021).

## 2.2 Challenges and limitations:

**2.2.1 Resistance to Pesticides:** Controlling medically significant arthropods is difficult because of pesticide resistance. Arthropod populations may become immune to chemical pesticides over time, making them less efficient at removing these organisms from the environment. This can happen due to behavioral adaptations that aid in avoiding exposure to

pesticides or genetic changes that allow the arthropods to detoxify or avoid the chemicals. Overuse or misuse of pesticides might select resistant individuals within the arthropod population, hastening the development of resistance. Once resistance has been established, it can be challenging and expensive to control since substitute pesticides might be less efficient or more expensive. Integrated pest control techniques are increasingly used to combat the problem of pesticide resistance. To lessen the need for chemical pesticides, they require using a variety of control strategies, such as biological control, environmental management, and personal protection (Gan et al., 2021).

**2.2.2 Lack of resources:** Lack of resources is another significant challenge in controlling medically important arthropods. This can encompass a variety of areas, including financial, human, and technical resources. Insufficient funding is available to implement effective control measures, such as pesticide spraying or mosquito net distribution programs. A lack of trained personnel to carry out inspections, implement control measures, or conduct research on medically important arthropods are defect in human resources. This can result in missed opportunities for early detection and intervention, potentially leading to the spread of diseases. Limited access to technical resources, such as diagnostic tools or pest management equipment can make it difficult to accurately identify infestations or implement effective control measures. Addressing the challenge of limited resources requires collaborative efforts between local governments, international organizations, research institutions, and the private sector (Schowalter, 2022).

**2.2.3 Difficulties in detecting infestations:** Many significant challenges in controlling medically important arthropods can be posed as the organisms can be small and elusive, making it difficult to accurately identify their presence in an area. In some cases, infestations may not be detected until after they have become well-established, allowing the arthropods to spread and potentially transmit diseases to human populations. This can be particularly challenging in remote or rural areas, where resources and personnel may be limited. To address this challenge, it is important to employ a range of detection methods, including visual inspections, the use of traps, and the examination of cargo manifests at ports of entry. Regular monitoring and surveillance can also help identify new infestations early and allow for timely control measures to be implemented. In addition, advances in diagnostic technologies, such as molecular techniques, can help improve the sensitivity and specificity of arthropod detection, making it easier to accurately identify infestations (McKirdy et al., 2019).

### 3. Results and Discussion

#### Future plan for controlling medically important arthropods using advanced technology

Advances in diagnostic technologies, such as molecular techniques, can help improve the sensitivity and specificity of arthropod detection, making it easier to accurately identify infestations and implement timely control measures.

#### 3.1 Early detection and monitoring:

**3.1.1 Surveillance:** Active surveillance programs can help to monitor the presence of arthropods in specific areas. The identification and monitoring of insect pests using automatic traps brings a novel approach to integrated pest management. Systems that use image recognition techniques and neural networks are the most studied ones, being reliable for the fully automatized identification of orders and counting of insects (Poh et al., 2022). Other promising image-based systems developed are the ones that aim to send the insect image to a specialist and then the insects could be identified and counted remotely in real-time. The infrared sensor traps were shown to be useful for counting insects, but are limited because they cannot identify the species, which can result in to misleading data in the survey. Many

models were developed using artificial neural networks (ANNs) for species identification. ANNs are computational models inspired by biological neural networks that can be trained to perform different tasks, such as identifying patterns in images (Flórián et al., 2023).

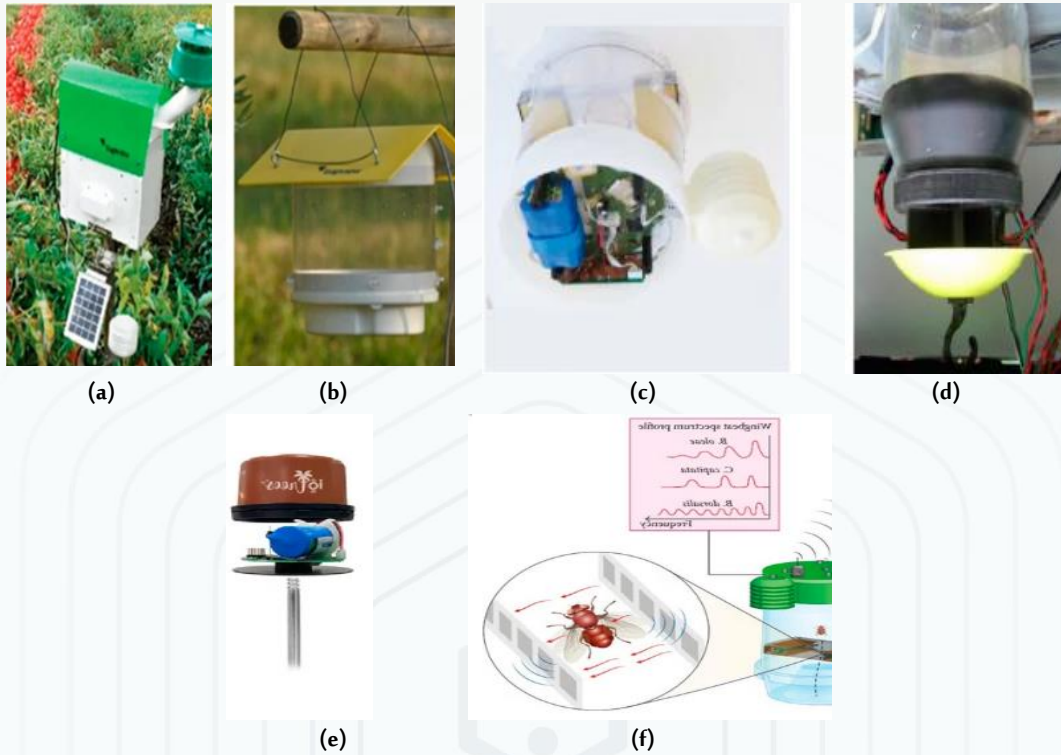


Figure 1. Examples of Automatic Traps

(a, b): Automatic trap for monitoring and detection of species, (c, d): Electronic traps: conventional traps converted to automatic fly monitoring units, (e, f): Echo-acoustic trap and sensor: (e): scheme detailing the functioning of an automatic acoustic insect trap. (f): Automatic detection device with seismic sensor for detection of weevils in trees.

**ANNs are future plans for controlling medically important arthropods (Movassagh et al., 2021):**

Artificial neural networks (ANNs) are computational models that are inspired by the structure and function of biological neural networks. ANNs can learn and adapt to new information, and as such, they have potential applications in the control of medically important arthropods. There are some ways in which ANNs could be used in the future to control arthropods. ANNs can be trained to predict the populations of medically important arthropods based on various factors such as climate, weather, and habitat data. This information can help authorities to better plan and implement pest control strategies. ANNs can be trained to identify images of pests in real time, allowing for quick and accurate identification of species. This can help authorities target specific species with appropriate control measures. Also, ANNs can be used to analyze data and identify the most effective control strategies for specific pest species. This can help authorities to optimize their pest control efforts and minimize the risk of disease transmission. In addition, ANNs can be used to monitor the development of pesticide resistance in medically important arthropods. By analyzing data on pesticide efficacy and pest populations, ANNs can help authorities identify resistance early and adjust control strategies

accordingly. Overall, the use of ANNs as a future tool for controlling medically important arthropods holds great potential. By improving prediction, identification, and optimization of control strategies, ANNs can help to minimize the risk of disease transmission and improve public health outcomes. However, further research and development are needed to fully realize the potential of ANNs in the control of medically important arthropods (Damos et al., 2021).

### 3.1.2 Reporting:

Encouraging the public to report any sightings of unusual species can help authorities quickly identify the presence of potentially dangerous arthropods.

### 3.1.3 Rapid identification:

Such as DNA-based techniques, can help to quickly identify the presence of specific pests and inform control efforts.

### 3.1.4 Monitoring:

Ongoing monitoring of pest populations can help to track changes in distribution, abundance, and potential disease risk. This can involve tracking the spread of pests over time and analyzing data to identify patterns or trends.

### 3.2 Pest Management:

It involves several approaches such as biological, chemical, cultural, and mechanical methods as mentioned before. Additionally, the development of new pesticides and biological control agents, such as mosquito-specific fungi, can help improve the effectiveness of control measures and reduce the environmental impact of pest management. Utilization of associated fungi could reduce mosquito development and arbovirus transmission or impact their behavior. Also, it may have a direct impact through the production of fungal toxins or the modulation of enzymatic activities (Malassigné et al., 2020).

Fungi may therefore interfere with vector competence by promoting or inhibiting the mosquito immune system (Bang, 2019). For example, yeasts are often used in attractive baits to generate biogenic CO<sub>2</sub>. Better knowledge of yeasts and their associated emitted VOCs might improve these techniques and open new avenues for the development of efficient mosquito control methods.

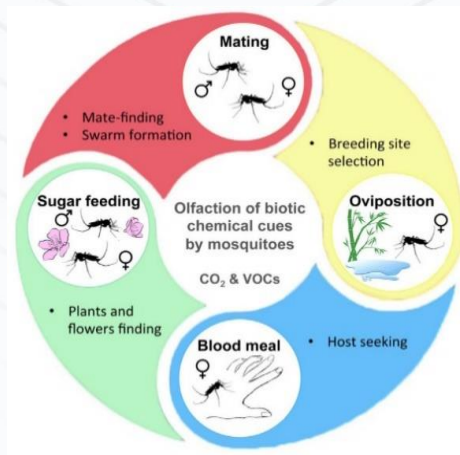


Figure 2. Influence of fungal volatile compounds on mosquito behavior.

Mosquitoes use olfactory perception of chemical cues and signals, such as CO<sub>2</sub> or volatile organic compounds (VOCs), to efficiently find flowering plants, mating partners, vertebrate hosts, or breeding sites favorable for larval development.

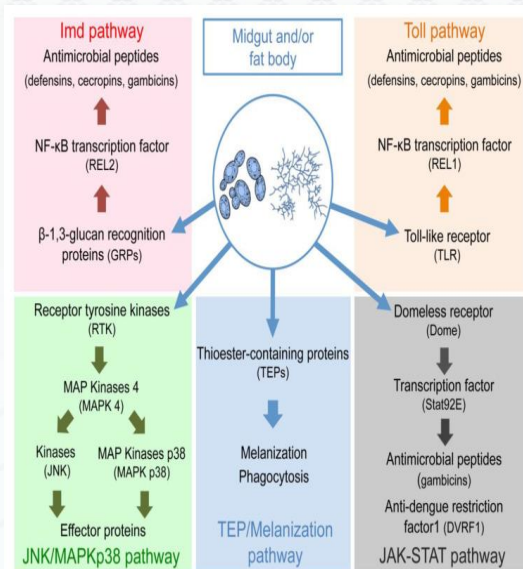


Figure 3. Signaling pathways of mosquito's innate immunity stimulated by fungi.

Fungal surface molecules or secondary metabolites are recognized by specific receptors. This recognition induces the activation of kinases or transcription factors that stimulate the production of antimicrobial peptides or other effector proteins as well as melanization and phagocytosis of fungal cells. Toll, Imd (Immune Deficiency), JAK/STAT (Janus Kinase/Signal Transducer and Activator of Transcription), JNK/MAPKp38 (Jun N-terminal Kinase/Mitogen-Activated Protein Kinase p38), TEP (ThioEstercontaining Protein) and immune melanization proteases are the different signaling pathways stimulated by fungi.

### 3.3 Remote sensing and geographic information systems (GIS):

These technologies offer several advantages, including the ability to gather large amounts of data quickly and efficiently, and to analyze and visualize that data in ways that can inform decision-making.

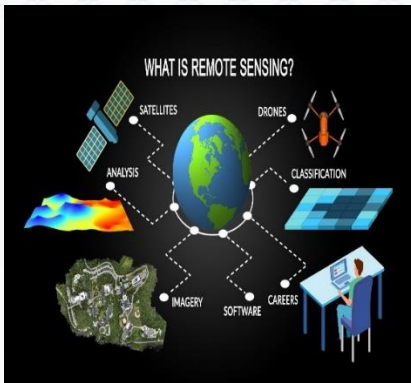
#### 3.3.1 Remote sensing (Klein et al., 2021):

Remote sensing has been defined as: "... the science of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object under investigation." Traditional methods of acquiring remote sensing data employ cameras or a variety of electronic sensing devices such as satellites, and aircraft, or that can be mounted on platforms located anywhere from a few meters to thousands of kilometers from the object of interest to capture images or other types of data from specific locations.

Remote sensing can be used to identify potential breeding sites, monitor changes in vegetation cover, and detect changes in land use that might affect arthropod populations.

#### 3.3.2 GIS (Singh et al., 2023 & Kouassi et al., 2023):

GIS technology involves the use of computer software to analyze, visualize, and interpret geographical data. In the context of arthropod control, GIS can be used to create maps showing the distribution of pest populations, identify areas at high risk for infestations, and plan effective control measures. By combining remote sensing and GIS, authorities can gain a better understanding of the factors that influence the spread and distribution of medically important arthropods and can use this information to develop targeted and effective control strategies.



What is Remote Sensing? The Definitive Guide



Geographic Information Systems Advanced GIS

Figure 4. Geographic Information Systems (GIS)

For example, if remote sensing data shows that a particular area has a large number of ponds or other water bodies that are ideal breeding sites for mosquitoes, GIS maps can be used to plan targeted interventions, such as the deployment of larvicides or mosquito traps in those areas.

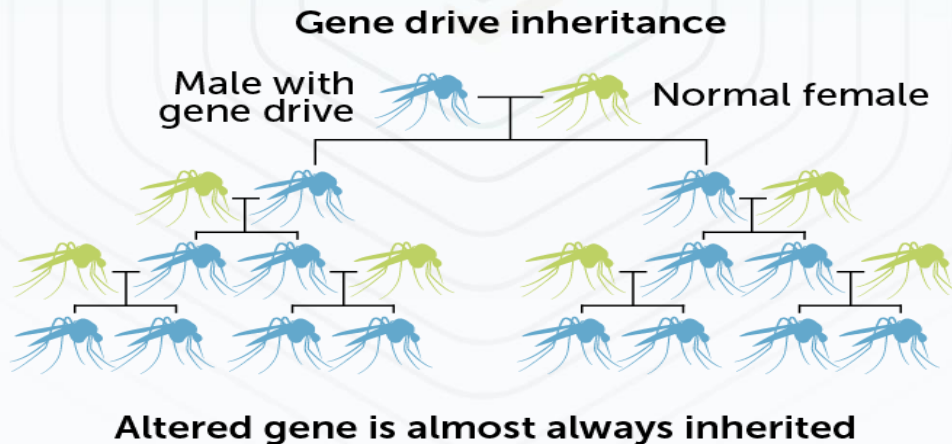
### 3.4 Genetic control:

It involves manipulating the genes or genetic material of pest populations to reduce their numbers or make them less harmful.

There are several approaches to genetic control, including:

#### 3.4.1 Gene drives (Bielza et al., 2020):

This approach uses genetic engineering to create a self-propagating genetic element that can spread rapidly through a pest population, potentially reducing its numbers or altering its traits.



Should we use a genetic weapon against mosquitoes carrying malaria?

Figure 5. genetic engineering

#### 3.4.2 Sterile insect technique (SIT) (Bourtzis and Vreysen, 2021):

This approach involves releasing large numbers of sterile male insects into the wild. When they mate with wild females, the resulting offspring are not viable, leading to a decline in the pest population over time.





### 3.4.5 E. Genetic modification of arthropod vectors (Tyagi et al., 2021):

Genetic engineering could be used to modify the genes of arthropod vectors, such as mosquitoes, to reduce their ability to transmit diseases. For example, a mosquito could be genetically modified to be resistant to a specific disease-causing pathogen, preventing it from spreading the disease.

Overall, genetic engineering has a significant potential as a future tool for controlling medically important arthropods. However, the use of genetic engineering in pest control raises ethical and environmental concerns that must be carefully considered before it can be widely implemented. Further research and development are needed to fully understand the potential benefits and risks of using genetic engineering to control medically important arthropods.

## 4. Conclusions and Recommendations

The current paper presents an overview of the current methods and technological advancements for controlling medically important arthropods, such as mosquitoes, sand flies, and ticks, during the Hajj and Umrah seasons in Saudi Arabia. Based on the findings presented in this paper, it is evident that the integration of new technologies can significantly enhance the efficiency of control measures for medically important arthropods. However, there are still challenges to overcome, such as the need for further research and development, addressing ethical concerns surrounding genetic modification, and ensuring the proper implementation of these technologies. Additionally, collaboration between researchers, public health officials, and religious authorities is crucial in effectively implementing these technologies and ensuring their acceptance among the public.

## References

1. Kouassi, B. L., Edi, C., Ouattara, A. F., Ekra, A. K., Bellai, L. G., Gouaméné, J., ... & Chabi, J. (2023). Entomological monitoring data driving decision-making for appropriate and sustainable malaria vector control in Côte d'Ivoire. *Malaria journal*, 22(1), 14. Available at: <https://link.springer.com/article/10.1186/s12936-023-04439-z>
2. Barzman, M., Bärberi, P., Birch, A. N. E., Boonekamp, P., Dachbrodt-Saaydeh, S., Graf, B., ... & Sattin, M. (2015). Eight principles of integrated pest management. *Agronomy for sustainable development*, 35, 1199-1215. Available at: <https://link.springer.com/article/10.1007/s13593-015-0327-9>
3. Robert Jr, L. L., & Debboun, M. (2020). Arthropods of public health importance. In Hunter's Tropical Medicine and Emerging Infectious Diseases (pp. 1055-1062). *Elsevier*. Available at: <https://www.sciencedirect.com/science/article/pii/B9780323555128001460>
4. Niang, E. H. A., Bassene, H., Fenollar, F., & Mediannikov, O. (2018). Biological control of mosquito-borne diseases: the potential of Wolbachia-based interventions in an IVM framework. *Journal of Tropical Medicine*, 2018. Available at: <https://www.hindawi.com/journals/jtm/2018/1470459/>
5. Dubey, S. C., Gupta, K., Akhtar, J., Chalam, V. C., Singh, M. C., Khan, Z., ... & Kumari, P. (2021). Plant quarantine for biosecurity during transboundary movement of plant genetic resources. *Indian Phytopathology*, 74(2), 495-508. Available at: <https://link.springer.com/article/10.1007/s42360-021-00375-7>
6. Roubos, C. R., Gautam, B. K., Fanning, P. D., Van Timmeren, S., Spies, J., Liburd, O. E., ... & Sial, A. A. (2019). Impact of phagostimulants on effectiveness of OMRI-listed insecticides used for control of spotted-wing drosophila (*Drosophila suzukii* Matsumura). *Journal of Applied Entomology*, 143(6), 609-625. Available at: [https://onlinelibrary.wiley.com/doi/abs/10.1111/jen.12620?casa\\_token=ktvitz-YaPIAAAAA%3AzHgljzkaM0bgrZ3xF03FAtlm5Jo9Flq42uSh4B46yWH8ZAGMjThzZs3dtjVIA1lyGnCDBh6BhpM32vVOFQ](https://onlinelibrary.wiley.com/doi/abs/10.1111/jen.12620?casa_token=ktvitz-YaPIAAAAA%3AzHgljzkaM0bgrZ3xF03FAtlm5Jo9Flq42uSh4B46yWH8ZAGMjThzZs3dtjVIA1lyGnCDBh6BhpM32vVOFQ)
7. van Oosterwijk, J. G., & Wikel, S. K. (2021). Resistance to ticks and the path to anti-tick and transmission blocking vaccines. *Vaccines*, 9(7), 725. Available at: <https://www.mdpi.com/2076-393X/9/7/725/pdf>

8. Gan, S. J., Leong, Y. Q., bin Barhanuddin, M. F. H., Wong, S. T., Wong, S. F., Mak, J. W., & Ahmad, R. B. (2021). Dengue fever and insecticide resistance in *Aedes* mosquitoes in Southeast Asia: a review. *Parasites & vectors*, 14(1), 1-19. Available at: <https://parasitesandvectors.biomedcentral.com/articles/10.1186/s13071-021-04785-4>
9. Schowalter, T. D. (2022). Insect ecology: an ecosystem approach. *Academic press*. Available at: <https://shop.elsevier.com/books/insect-ecology/schowalter/978-0-323-85673-7>
10. McKirdy, S. J., O'Connor, S., Thomas, M. L., Horton, K. L., Williams, A., Hardie, D., ... & van der Merwe, J. (2019). Biosecurity risks posed by a large sea-going passenger vessel: challenges of terrestrial arthropod species detection and eradication. *Scientific reports*, 9(1), 19339. Available at: <https://www.nature.com/articles/s41598-019-55554-4>
11. Poh, K. C., Evans, J. R., Skvarla, M. J., & Machtinger, E. T. (2022). All for One Health and One Health for All: considerations for successful citizen science projects conducting vector surveillance from animal hosts. *Insects*, 13(6), 492. Available at: <https://www.mdpi.com/2075-4450/13/6/492>
12. Flórián, N., Jósvali, J. K., Tóth, Z., Gergőcs, V., Sipőcz, L., Tóth, M., & Dombos, M. (2023). Automatic Detection of Moths (Lepidoptera) with a Funnel Trap Prototype. *Insects*, 14(4), 381. Available at: <file:///C:/Users/ashra/Downloads/insects-14-00381-v2-2.pdf>
13. Damos, P., Tuells, J., & Caballero, P. (2021). Soft computing of a medically important arthropod vector with autoregressive recurrent and focused time delay artificial neural networks. *Insects*, 12(6), 503. Available at: <file:///C:/Users/ashra/Downloads/insects-12-00503.pdf>
14. Movassagh, A. A., Alzubi, J. A., Gheisari, M., Rahimi, M., Mohan, S., Abbasi, A. A., & Nabipour, N. (2021). Artificial neural networks training algorithm integrating invasive weed optimization with differential evolutionary model. *Journal of Ambient Intelligence and Humanized Computing*, 1-9. Available at: <https://link.springer.com/article/10.1007/s12652-020-02623-6>
15. Malassigné, S., Valiente Moro, C., & Luis, P. (2020). Mosquito mycobiota: an overview of non-entomopathogenic fungal interactions. *Pathogens*, 9(7), 564. Available at: <file:///C:/Users/ashra/Downloads/pathogens-09-00564-1.pdf>
16. Bang, I. S. (2019). JAK/STAT signaling in insect innate immunity. *Entomological Research*, 49(8), 339-353. Available at: <https://onlinelibrary.wiley.com/doi/full/10.1111/1748-5967.12384>
17. Klein, I., Oppelt, N., & Kuenzer, C. (2021). Application of remote sensing data for locust research and management—A review. *Insects*, 12(3), 233. Available at: [https://onlinelibrary.wiley.com/doi/abs/10.1111/1748-5967.12384?casa\\_token=3mC503VKu0IAAAAA%3A\\_Q1P90Gaq5bVNQ4\\_JltN5s0ZTKq9vHkettucMsTZrkr9fHgL\\_XG6M7p2C1B3iN-d2hnONzyLiwQmvyVBw](https://onlinelibrary.wiley.com/doi/abs/10.1111/1748-5967.12384?casa_token=3mC503VKu0IAAAAA%3A_Q1P90Gaq5bVNQ4_JltN5s0ZTKq9vHkettucMsTZrkr9fHgL_XG6M7p2C1B3iN-d2hnONzyLiwQmvyVBw)
18. Singh, M., Vermaa, A., & Kumar, V. (2023). Geospatial technologies for the management of pest and disease in crops. In *Precision Agriculture* (pp. 37-54). *Academic Press*. Available at: [https://www.researchgate.net/publication/342243912\\_Geospatial\\_Technology\\_for\\_Plant\\_Disease\\_and\\_Insect\\_Pest\\_Management](https://www.researchgate.net/publication/342243912_Geospatial_Technology_for_Plant_Disease_and_Insect_Pest_Management)
19. Bielza, P., Balanza, V., Cifuentes, D., & Mendoza, J. E. (2020). Challenges facing arthropod biological control: identifying traits for genetic improvement of predators in protected crops. *Pest management science*, 76(11), 3517-3526. Available at: [https://onlinelibrary.wiley.com/doi/abs/10.1002/ps.5857?casa\\_token=0vOEIkQIMFEAAAA%3A-2MWZfzFTssuj9WpR3i3iW6eejmtLb49cYCNEap9VbystoKBf3XoX97ujxnPVTAXUFCyYbNals02cLSnsAg](https://onlinelibrary.wiley.com/doi/abs/10.1002/ps.5857?casa_token=0vOEIkQIMFEAAAA%3A-2MWZfzFTssuj9WpR3i3iW6eejmtLb49cYCNEap9VbystoKBf3XoX97ujxnPVTAXUFCyYbNals02cLSnsAg)
20. Bourtzis, K., & Vreysen, M. J. (2021). Sterile insect technique (SIT) and its applications. *Insects*, 12(7), 638. Available at: <https://www.mdpi.com/2075-4450/12/7/638>
21. Zotti, M., Dos Santos, E. A., Cagliari, D., Christiaens, O., Taning, C. N. T., & Smagghe, G. (2018). RNA interference technology in crop protection against arthropod pests, pathogens and nematodes. *Pest management science*, 74(6), 1239-1250. Available at: [https://onlinelibrary.wiley.com/doi/abs/10.1002/ps.4813?casa\\_token=UX1wNTQKsjgAAAA%3A108CphdiCOA-FfUPjyFJ8Gs9MD1AhdpzE35EAWlag8S553apvAzCn2z94yxTIVqTXA\\_8SqKw22E-hH6POw](https://onlinelibrary.wiley.com/doi/abs/10.1002/ps.4813?casa_token=UX1wNTQKsjgAAAA%3A108CphdiCOA-FfUPjyFJ8Gs9MD1AhdpzE35EAWlag8S553apvAzCn2z94yxTIVqTXA_8SqKw22E-hH6POw)
22. Tyagi, B. K., Basu, P., & Bhattacharya, S. (2021). Genetically modified and other innovative vector control technologies. *Springer Singapore*. Available at: <https://www.researchgate.net/profile/Kamlesh-Yadav>

[2/publication/357483788\\_Evaluation\\_of\\_Transgenic\\_Aedes\\_aegypti\\_L\\_Strain\\_in\\_India\\_A\\_Friendly\\_Mosquito/links/64193de766f8522c38bf9cd7/Evaluation-of-Transgenic-Aedes-aegypti-L-Strain-in-India-A-Friendly-Mosquito.pdf](https://www.mdpi.com/2071-1050/13/21/11999)

23. World Health Organization (2020). The WHO recommended classification of pesticides by hazard and guidelines to classification 2019. *World Health Organization*. Available at: <https://www.who.int/publications-detail-redirect/9789240005662>

24. Ghiglieno, I., Simonetto, A., Sperandio, G., Ventura, M., Gatti, F., Donna, P., ... & Gilioli, G. (2021). Impact of environmental conditions and management on soil arthropod communities in vineyard ecosystems. *Sustainability*, 13(21), 11999. Available at: <https://www.mdpi.com/2071-1050/13/21/11999>





## “Nafee Application”: Utilizing facial recognition technology to speed up hospital procedures when obtaining pilgrim visas

Maarib A. Alsulimani, Ghala A. Alharbi Randa M. Alminami, Nujud A. Althagafi, and Olfat M. Mirza

Department of Computer science and Artificial Intelligence, Umm Al-Qura University

\*Corresponding author: E-mail (maarib.alsulimani@gmail.com)

## تطبيق نافع : الاستفادة من تقنية التعرف على الوجه لتسريع إجراءات المستشفى عند الحصول على تأشيرات الحجاج

مآرب عبدالله السليماني، غلا عدنان الحربي، رندا منصور المنعمي، نجاد عبدالرزاق الثقفي، ألفت معراج مرزا

قسم علوم الحاسب والذكاء الاصطناعي، جامعة أم القرى

### المخلص

تعتبر عملية التحقق من تأشيرات الحجاج خلال فترة الحج في المستشفيات بالمملكة العربية السعودية تحديًا يواجه العديد من المستشفيات التي تتعامل مع حجاج الخارج. وينتج هذا التحدي عن تنوع الجنسيات واختلاف اللغات وعدم إدراك الحجاج لأهمية تأشيرات الحج الخاصة بهم للمستشفيات. لذلك، يهدف هذا البحث إلى تطوير تطبيق يساعد في تسهيل عملية التحقق من تأشيرات الحجاج باستخدام تقنية التعرف على الوجه. تم تنفيذ التطبيق باستخدام منهجية الشلال (waterfall) للتطوير، حيث تم تحليل المتطلبات ثم تصميم وبناء التطبيق واختباره. يستخدم التطبيق خوارزميات HOG (Histogram of Oriented Gradients) و CNN (Convolutional Neural Network) و K-NN (K-Nearest Neighbours) لتحديد الوجوه في الصورة واستخراج المعالم الفريدة ومقارنتها مع المعالم المخزنة لتحقيق التعرف على الوجه. يتم تحديد المطابقة بناءً على قيمة الاختلاف بين الوجوه، وتم تحسين كفاءة الخوارزمية بواسطة تحديد عتبة الاختلاف بقيمة 0.5 لتجنب تشبيه صور الأشخاص الملتقطة بأقرب شبيه لهم في قاعدة البيانات وضمان نتائج بدقة عالية، تم إجراء التدريب على جميع الأفراد البالغ عددهم 96 فرداً، وتم استخراج ملامح الوجه لهم جميعاً، ومن ثم تم اختيار 25 فرداً منهم بشكل عشوائي لإجراء الاختبار، تم التعرف على 24 شخص بشكل صحيح من أصل 25، بنسبة دقة وصلت إلى 96%، تم أيضاً إجراء تجارب على خمسة أفراد تم التقاط صور لهم في وقتين مختلفين، وأظهرت النتائج تشابهاً قريباً في النتائج بين الصور بفرق متوسط يبلغ حوالي 0.0522، حتى مع وجود فجوات زمنية كبيرة بين الصور لبعض الأفراد. تطبيق نافع يساعد على تسريع الإجراءات إلى حد كبير، ويقلل من أخطار الاحتيال، ويعزز التجربة الشاملة للحجاج أثناء زيارتهم للمستشفى.

الكلمات الدالة: حاج، تأشيرة، التعرف على الوجه، الذكاء الاصطناعي، مستشفى.

### Abstract

Verifying pilgrims' visas during the Hajj season in hospitals in the Kingdom of Saudi Arabia poses a challenge for many hospitals dealing with foreign pilgrims. This challenge arises from the diversity of nationalities, language differences, and pilgrims' lack of awareness of the importance of their Hajj visas to hospitals. Therefore, this research aims to develop an application that facilitates the process of verifying pilgrims' visas using face recognition technology. The application was

implemented using the waterfall development methodology, where requirements were analysed, and the application was designed, built, and tested. The application utilizes HOG (Histogram of Oriented Gradients), CNN (Convolutional Neural Network), and K-NN (K-Nearest Neighbours) algorithms to detect faces in the image, extract unique features, and compare them with stored features to achieve face recognition. The matching is determined based on the difference value between faces, and the algorithm's efficiency was improved by setting a difference threshold of 0.5 to avoid matching captured images of individuals with their closest match in the database and ensure high-precision results. Training was conducted on all 96 adult individuals, and their facial features were extracted. Then, 25 individuals were randomly selected for testing, and 24 individuals were correctly identified out of 25, with an accuracy rate of 96%. Additionally, experiments were conducted on five individuals whose pictures were taken at separate time intervals, and the results showed a close similarity between the images with an average difference of approximately 0.0522, even with significant time gaps between the images for some individuals. This beneficial application helps significantly accelerate procedures, reduces the risk of fraud, and enhances the overall experience for pilgrims during their hospital visits.

**Keywords:** Pilgrim , Visa , Facial Recognition , Artificial Intelligence , Hospital.

### Introduction

The Kingdom of Saudi Arabia is always keen on the comfort of pilgrims and Umrah performers by providing everything that contributes to presenting the Hajj and Umrah season to the fullest. The Kingdom kept pace with the technical development to take advantage of technology in serving all fields, especially in the field of Hajj and Umrah, and maintaining the safety and comfort of pilgrims in all organizations, and we saw this in the Corona epidemic, as the great and rapid technical development was observed in the emergence of many mobile phone applications that contribute to ensuring The health of pilgrims and Umrah performers such as the "صحتي" application, as well as what contributes to detecting virus carriers such as the "تباعد" application, and what is related to visiting the Grand Mosque and following up the numbers of pilgrims and rationing them such as the "نسك" application, in addition to other digital technologies to track and manage crowds as shown in Figure 1, and to maintain That is, we must always track the simplest problems that face the pilgrims and Umrah performers every year to develop solutions and preserve what we are used to seeing from our Kingdom's efforts in serving the pilgrims and Umrah performers.[1][2].

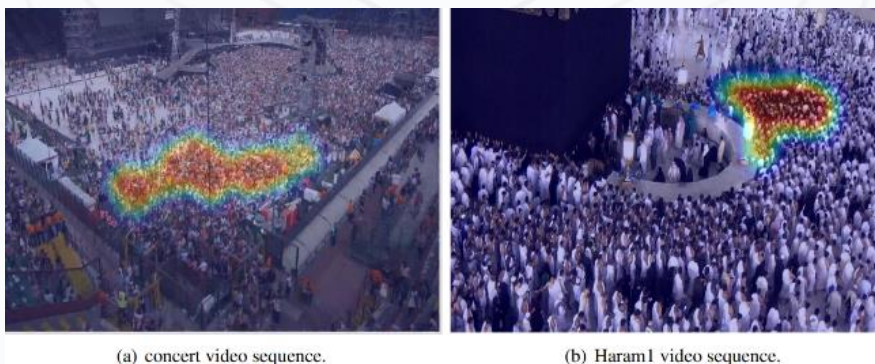


Figure1: Some of the technology used in *Masjid-al-Haram*: Detection of crowded places

The Kingdom provides dedicated paths for both internal and external pilgrims to apply for the Hajj season, so the Kingdom provides the Hajj application for domestic pilgrims through the "نسك" application or the website of the Ministry of Hajj and Umrah, as for outside pilgrims, the Kingdom has provided the "نسك حج" for Hajj approved by the Ministry of

Hajj and Umrah for those coming from countries Europe and the Americas and Australia, in addition, each country determines for its citizens the approved platform apply for the Hajj season, as an example India: Hajj is organized in India through the "Ministry of External Affairs" platform (<https://www.haj.gov.in/>) that allows pilgrims to register and apply for Hajj, Indonesia: Hajj is organized in Indonesia through the "Ministry of Religious Affairs" platform (<https://haji.kemenag.go.id/>) that allows pilgrims to register and apply for Hajj. the competent authorities require several documents to complete the Hajj registration procedures, and among the most important requirements: are a copy of the passport and a personal photo of the applicant, if the application is accepted, the Hajj visa is issued to the pilgrim, which is his unique identity in the Kingdom, Figure 2 shows the form of the electronic visa issued to the pilgrim.[3].



Figure 2 : The Electronic Visa

In our search for problems to try to develop, we found that hospitals are among the organizations that face the most problems every year in dealing with pilgrims and taking the necessary information to complete the procedures, due to some pilgrims losing their important documents, which is visas, so it is difficult to identify them with the competent authorities and to find out their data and complete their procedures, the organizations must contact with the companies and offices from which the pilgrim came, this process takes some time and hinders the progress of things, so we decided to solve this problem and use artificial intelligence technology, especially the field of face recognition, to identify the person and quickly access the data required for him.

**Methodology**

The project aims to improve the pilgrims’ visa verification process using a Nafee application that utilizes facial recognition technology. This will improve work efficiency in hospitals during the Hajj period, and enhance the pilgrims’ experience by providing a convenient and efficient way to verify their visas, reducing the time taken in the process. The waterfall methodology was adopted in developing the Nafee application, which includes the following steps: requirements gathering, design, implementation, verification testing, and maintenance.

The requirements of the application were collected in a way that suits the category that benefits from the application, which is hospitals based on the survey conducted and the response of hospital workers, it was found that there are problems facing pilgrims during their admission to the hospital. The first of these problems was identified as the difficulty

of understanding and the difference in languages, and the second was the pilgrims forgetting their visas and their bracelets. The application includes features such as logging in or creating an account for hospital, the ability to access the camera and take a picture of the pilgrim, then retrieve the pilgrim’s visa from the database and display it on the application interface after identifying the pilgrim, and procedures or statuses can be written for the pilgrims. If necessary, the application also provides access to a list that includes all sick pilgrims present in the hospital who have been identified through the application, and the procedures for them through the list can be modified, procedures or removed the pilgrim from this list. After that, the interfaces were designed in a simple, easy-to-use design, with quick access to the camera as much as possible. The following figure 3 shows how the Nafee application works.

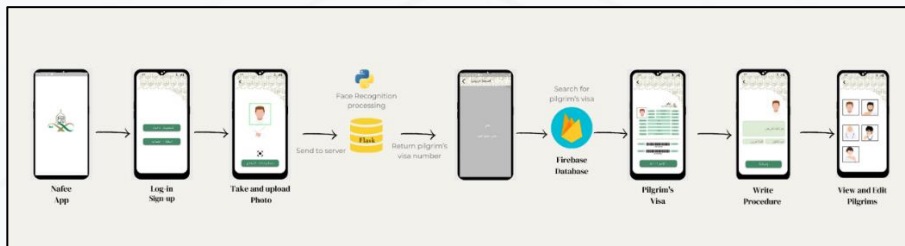


Figure.3 : Nafee application workflow

For the data set, a set of photos was collected from the Internet, including 96 individuals of different nationalities and ages. To train the model, 6 or more images of each person in different poses and time periods. It is worth noting that part of the data used for training included images of real pilgrims obtained from a concerned party, Training was conducted on all 96 individuals, facial features were extracted for all of them, and then 25 individuals were randomly selected from them to conduct the test.

During the implementation phase, a variety of tools were used. Android Studio served as the Integrated Development Environment (IDE), While Flutter was used as the framework to build the application, Dart SDK version 3.1.0 was used. Flask and Ngrok were employed to create a local host server. Firebase was chosen as the database for storing visas, hospital data, and pilgrims, Figure 4 shows the hierarchical structure of the database. Python version 3.11.4 was utilized for processing and implementing the facial recognition algorithms.

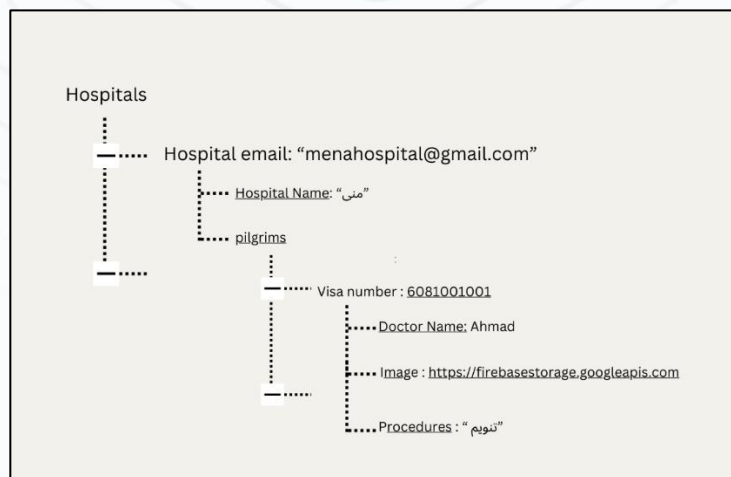


Figure 4 : The hierarchical structure of the database



The face\_recognition library, which is one of the best and easiest dlib-based libraries, was used in Python for face recognition tasks.[4] This library employs the HOG algorithm (Histogram of Oriented Gradients) as a preprocessing step to detect facial landmarks and align the face within the image. The HOG algorithm analyzes pixel gradients and orientations to capture significant information regarding edges and patterns in the image[5].

For extracting unique facial features, the library utilizes CNN (Convolutional Neural Network). This function employs a deep neural network model to analyze images and extract distinctive features that can be used for face recognition[6]. Furthermore, the face\_recognition library leverages the K-NN (k-Nearest Neighbors) algorithm for classifying new faces based on the nearest neighbors in the training dataset. This algorithm helps in identifying the most similar faces to the given input by comparing their extracted features .

In general, based on the algorithms used, the application falls within the fields of image processing, computer vision, deep learning, and artificial intelligence-based classification.

It is used by the function that extracts the unique facial features from the given image. A deep neural network model is used to analyze images and extract unique features.

In addition, the K-NN (k-Nearest Neighbors) algorithm in the library was used to classify new faces based on the nearest neighbors in the training dataset. [7].

## Results and Discussion

The accuracy was calculated to evaluate the performance of the model using a test set consisting of a number of individuals whose facial features were extracted during the encoding phase. The test group comprised 25 individuals out of 96, and 24 of them were correctly classified out of the total 25 individuals in the test group.

Model accuracy was calculated using the following formula:

Accuracy = (number of correctly classified images / total number of images in the test set) x 100

Accuracy = (24/25) x 100 = 96%

The model accuracy was achieved at 96%. This high level of accuracy indicates that the model is effective in face recognition tasks. To improve the algorithm's efficiency, a difference threshold percentage of 0.5 was introduced. This ensures high accuracy in determining the identity of the individuals whose photos are taken compared to the existing pictures of them in the database. Previously, the algorithm would identify the closest resemblance to the person in a captured image if they were not recognized in the database, resulting in the absence of an unknown face scenario.

By incorporating the difference threshold of 0.5, the algorithm ensures that the identified person must have a face distance below the threshold, indicating a high level of similarity. If the face distance exceeds this threshold, the algorithm considers the person as "Unknown" or not present in the database. This approach improves efficiency by increasing the accuracy of correctly identifying individuals, and improvements the algorithm's reliability and its ability to handle cases where the face to be identified may not precisely match a stored image, providing more accurate and robust results.

In the comparison process, the extracted features of the face in the processed image are compared with the known features stored. This involves calculating the difference value between the faces, which ranges from 0 to 1, with values closer to 0 representing more accurate matches.

To determine the matching face, The algorithm searches for the face in the dataset with the lowest difference value closest to 0. If a matching face is found and the difference value is below the specified threshold (0.5), the person is identified and sends his visa number to the server for processing.

In our experiment, we captured images of five individuals at two different time points. The table below shows the results obtained from photographing each person. The first column represents the most recent image of the individual, while the second column represents an image taken at the close time from the image used to train the model. It is worth noting that there are large time gaps between the two images for some individuals, extending for several years. Despite this, the results were positive and showed close similarity, with an average difference of about 0.0522.

Table.1 : Imaging results for 5 individuals

Person	Recent Photo	Oldest photo
1	0.435	0.360
2	0.384	0.280
3	0.408	0.359
4	0.407	0.387
5	0.389	0.376

These findings provide evidence of the model's consistent performance in accurately recognizing and matching facial features, The small average difference indicates the robustness and reliability of the trained model in identifying individuals across Far apart time intervals.

The accuracy of face recognition in the Nafee application is crucial. The model used in the application needs this accuracy to address the various changes in the appearance of pilgrims as a result of climatic conditions, travel, and fatigue when they arrive at the hospital.

**Conclusions**

In conclusion, Nafee is an application that addresses the challenges faced by hospitals during the Hajj period, specifically the disruption of procedures due to visa unavailability. The application's person recognition accuracy, estimated at 96%, coupled with an extremely low rate of false result, ensures the delivery of accurate results.

Comprehensive test conducted across different time periods demonstrated good results, with a minimal difference of 0.0522. These findings underscore the suitability and practicality of Nafee in the Hajj environment and hospitals, effectively achieving its intended objective.

By expediting procedures and leveraging technology, the Nafee application offers significant benefits in serving the guests of Allah and enhancing the pilgrims' healthcare experience. Its implementation contributes to streamlining processes and improving healthcare services in the sector.

**Recommendations**

In order to enhance the Nafi application and expand its capabilities, the following recommendations are proposed:

Improving performance and expanding the database: Utilize cloud databases to improve performance, accelerate data retrieval, and handle larger data sets.

Introducing Natural Language Processing (NLP) technology: Implement NLP technology to understand and translate the languages of pilgrims. This will expedite hospital admission procedures by facilitating communication between healthcare providers and pilgrims. Integrating NLP into Nafee will enhance its functionality and usability.

Generalizing the Nafee application and making it accessible to another organizations: Explore the possibility of extending the application's usage beyond hospitals. This can benefit other institutions, such as identifying missing or unauthorized pilgrims. Supporting multiple languages will further increase its utility.

Establishing partnerships with relevant organizations and entities: Enable the sharing the list of pilgrims present in hospitals with relevant authorities, allowing for improved collaboration among multiple parties. Additionally, create administrative accounts for authorized entities to access and view patient data from the pilgrim list.

By implementing these recommendations, the Nafi application can be enhanced to better serve the needs of hospitals and other organizations involved in managing the Hajj pilgrimage.

## References

- [1] Binsawad, M. and Albahar, M. (2022) 'A technology survey on IOT applications serving Umrah and Hajj', *Applied Computational Intelligence and Soft Computing*, 2022, pp. 1–10. doi:10.1155/2022/1919152.
- [2] Ali, M.F., Bashar, A. and Shah, A. (2015) 'Smartcrowd: Novel Approach to Big Crowd Management using mobile cloud computing', *2015 International Conference on Cloud Computing (ICCC)* [Preprint]. doi:10.1109/cloudcomp.2015.7149656.
- [3] Abalkhail, A.A. and Al Amri, S.M. (2022) 'Saudi Arabia's management of the Hajj season through Artificial Intelligence and Sustainability', *Sustainability*, 14(21), p. 14142. doi:10.3390/su142114142.
- [4] Ageitgey, A. (2022) *Ageitgey/face\_recognition: The world's simplest facial recognition API for python and the command line, GitHub*. Available at: [https://github.com/ageitgey/face\\_recognition](https://github.com/ageitgey/face_recognition) (Accessed: 02 December 2023).
- [5] Zhang, S. and Wang, X. (2013) 'Human detection and object tracking based on histograms of oriented gradients', *2013 Ninth International Conference on Natural Computation (ICNC)* [Preprint]. doi:10.1109/icnc.2013.6818189.
- [6] Li, Z. *et al.* (2022) 'A survey of Convolutional Neural Networks: Analysis, applications, and prospects', *IEEE Transactions on Neural Networks and Learning Systems*, 33(12), pp. 6999–7019. doi:10.1109/tnnls.2021.3084827.
- [7] Happiness, O. (2023) *Performing face recognition using KNN, Medium*. Available at: <https://medium.com/shocodeafrica/performing-face-recognition-using-knn-fe71d87ab619> (Accessed: 03 December 2023).



## Address the Gap between Healthcare Services and Healthcare Receiver during Hajj and Umrah

Bayan Muteb Aldhahwani\*, Moiyad Saleh Aljehani

Department of Medical Rehabilitation Sciences, Umm Al-Qura University

\*Corresponding author: E-mail (bmdhahwani@uqu.edu.sa)

### معالجة الفجوة بين الخدمات الصحية ومتلقي الرعاية الصحية خلال الحج والعمرة

بيان متعب الظهواني\*، مؤيد صالح الجهني

قسم علوم التأهيل الطبي، جامعة أم القرى

#### الملخص

يعد الحج والعمرة حدثين ضخمين، يجذب سنوياً الملايين من المسلمين، مما يجعلها من أكبر التجمعات البشرية على مستوى العالم. الحج والعمرة يطرحان تحديات صحية فريدة وتتمثل هذه التحديات الرئيسية في: الوصول المحدود للمرافق الطبية بسبب الازدحام، الاختلافات الثقافية، الحواجز اللغوية، قلة الوعي بالخدمات الصحية المتاحة، ومشكلات التنسيق بين مقدمي الخدمات الصحية.

يزيد عدم توفير الخدمات الرعاية الصحية سريعاً، خاصة في حالات الطوارئ، من المخاطر الصحية والوفاة بين الحجاج. كما أن الظروف المزدحمة تؤدي إلى إجهاد المرافق الصحية بحالات غير طارئة مما يقلل من جودة الرعاية الطبية المقدمة. بالإضافة إلى أنه قد تتفاقم الحالات المزمنة بدون التدخل الطبي في الوقت المناسب. ويمكن أن يكون لتأخير الرعاية الصحية تأثير نفسي كبير على ضيوف الرحمن مما يؤثر على تجربة أداء فريضة الحج والعمرة. وأثار تأخير تقديم الرعاية الصحية قد تمتد أيضاً إلى ما بعد انتهاء موسم الحج والعمرة، حيث أنه قد تؤدي إلى إجهاد الأنظمة الصحية، إرهاق خدمات الطوارئ والتأثير السلبي على اقتصاد المملكة.

لمواجهة هذه الفجوة الحالية بين مقدمي الخدمات الصحية والحجاج، نترح تطوير تطبيق صحي ذكي يتكامل مع الذكاء الاصطناعي (AI)، وبشكل خاص التعلم الآلي (ML). حيث يقدم مزايا أساسية مثل دعم عدة لغات ومعلومات الطوارئ، وايضا يطرح خصائص متقدمة مثل فحص الأعراض الصحية لضيوف الرحمن وتقييم المخاطر. من خلال السماح للحجاج بإدخال أعراضهم المرضية، يمكن للتطبيق إجراء تقييم أولي للمخاطر وتقديم نصائح مخصصة للخطوات التي يجب اتباعها، سواء كان ذلك الحصول عن عناية طبية فورية، أو تقديم استشارات صحية افتراضية، أو تدابير الرعاية الذاتية البسيطة. سيساعد ذلك في تقليل الأعباء والزيارات غير الضرورية للمراكز الطبية. أيضاً يمكن للتطبيق ان يكون متصلاً بمراكز الخدمات الطبية في المشاعر المقدسة (المسجد الحرام، منى، عرفة، مزدلفة)، مما يمكن أقرب مركز طبي من توفير المساعدة الفورية للحجاج المحتاجين. هذا التواصل سيعزز الاستجابة السريعة والتدخل الطبي الفعال.

دمج حلول الصحة الرقمية مع الأنظمة الصحية الحالية في الحج يعزز الكفاءة وتنسيق البيانات لتحقيق مخرجات صحية أفضل. ستساهم هذه الأداة الرقمية في تعزيز سلامة الحجاج وصحتهم وتجربتهم خلال الحج والعمرة.

الكلمات الدالة: الحج، تطبيق الهاتف المحمول، الخدمات الطبية، الاستجابة الطبية للطوارئ، حلول الصحة الرقمية.

## Abstract:

Hajj and Umrah, essential Islamic pilgrimages, annually attract millions, making them some of the largest human gatherings globally. Hajj and Umrah present unique healthcare challenges, including limited access to medical facilities because of overcrowding, cultural differences, language barriers, a lack of awareness about healthcare services, and systemic coordination issues between healthcare providers.

The lack of rapid medical response, especially in emergencies, heightens the risks of mortality and morbidity. Further, crowded conditions will overburden the healthcare facilities with non-emergency cases and can lead to a decrease in the quality of care provided. Chronic conditions may worsen without timely care, and the psychological impact of inadequate healthcare can significantly affect the pilgrimage experience. Post-Hajj and Umrah, these issues can strain healthcare systems, overburden emergency services, and negatively impact the Kingdom's economy.

To address the current gap between healthcare services and receivers, we propose developing a specialized mobile health application integrated with Artificial Intelligence (AI), particularly Machine Learning (ML). The proposed app would offer basic features like a multilingual interface and emergency information; also, include advanced functionalities like symptom checking and risk assessment tools. By allowing pilgrims to input their symptoms, the app can perform an initial risk assessment and provide tailored advice on the next steps, whether it's seeking immediate medical attention, virtual healthcare consultations, or simple self-care measures. This will help balance the patient load and reduce unnecessary visits to medical stations. Crucially, the app would be connected to medical service stations in the Holy Sites (Grand Masjid, Mina, Arafat, and Muzdalifah), enabling the nearest station to provide immediate assistance to pilgrims in need. This connection ensures rapid response and effective medical interventions.

Integrating digital health solutions with the current healthcare systems in the Hajj enhances efficiency and data coordination for better healthcare outcomes. The digital tool will significantly enhance pilgrim safety, health, and experience during Hajj and Umrah.

**Keywords:** Hajj, Mobile Application, Medical Services, Emergency Healthcare, Digital Health Solutions.

## 1. Introduction

The Hajj and Umrah pilgrimages, one of the world's largest mass gatherings, pose significant public health challenges. Over the last four years, the number of pilgrims exceeds 2 million (Statistics, 2019, 2022, 2023). This influx of pilgrims to the holy city of Mecca represents a unique challenge in terms of public health and safety management. The systematic review of literature from 2005-2014 on health risks and services during Hajj highlights concerns in three main categories: communicable diseases, noncommunicable diseases, and health services (Aldossari et al., 2019).

The healthcare challenges during Hajj and Umrah are multifaceted due to the immense crowd density, diversity of the pilgrims' backgrounds, and complex logistics of delivering care in such conditions. Overcrowded conditions often result in overburdening healthcare facilities with non-emergency cases, thereby decreasing the quality of care available for more serious conditions. The lack of awareness among pilgrims about available healthcare services, along with the logistical difficulties in accessing these services, exacerbates the situation. Additionally, the lack of rapid medical response, especially in emergencies, further elevates the risks of mortality and morbidity. These factors collectively contributed to creating a gap between healthcare services and receivers during the Hajj and Umrah pilgrimages.

The Saudi Ministry of Health, in line with the Kingdom's 2030 vision, is determined to offer advanced free medical services to pilgrims, emphasizing the need for digital transformation and a unified electronic platform for healthcare

applications. The Hajj season is a significant challenge for various sectors, including healthcare. The government and private sectors attempt to provide comprehensive services to pilgrims, focusing on health and safety. This includes preparing strategic plans for health logistics services through e-government and developing a Hajj Health Information System (HHIS) for data sharing and better public health intervention (Aljohani et al., 2022). Despite the improvements in healthcare services over the years, the current gap in healthcare services and receivers persists, necessitating continued improvement in the digital healthcare services provided to pilgrims.

To bridge the gap between healthcare services and receivers, the development of a specialized mobile health application targeted at pilgrim needs is essential. Therefore, in this study, we propose the development of a healthcare application that provides advanced functionalities that integrated with Artificial Intelligence (AI), in particular, Machine Learning (ML). Further, the proposed digital solution objects to enhance the efficiency and effectiveness of healthcare delivery by integrating with medical care stations in the Holy sites and current healthcare systems to ensure rapid medical response.

## 2. Literature Review

### 2.1 Existing Healthcare Applications

In preparation for developing a comprehensive digital health solution for Hajj and Umrah pilgrims, an extensive search of the following databases was conducted: The Unified National Platform, Saudi Red Crescent Authority (SRCA), Ministry of Health, and Ministry of Hajj and Umrah (*Ministry of Hajj and Umrah*; *Ministry of Health*; *Saudi Red Crescent Authority (SRCA)*; *The Unified National Platform. Hajj and Umrah*). The aim was to identify existing digital health services and their functionalities, assess gaps, and understand how new solutions could enhance pilgrims' support. After conducting a detailed search for the applications related to healthcare for Hajj and Umrah pilgrims, we found two existing applications (Asefny and Sehha) (*Ministry of Health*; *Saudi Red Crescent Authority (SRCA)*; *The Unified National Platform. Hajj and Umrah*) that focus on specific areas of health management and support.

After identifying the existing applications, an analysis of the content of each healthcare application compared to the proposed health app was conducted. The search findings are shown in Table 1, where the first column shows the App name (this refers to the official name of the application as it appears in app stores or marketing materials). The "Primary Function" item details the main purpose or key functionality of the app, such as providing emergency assistance, medical consultations, or Personalized Self-care Management. The "Symptom Checker" item notes whether the app includes a feature that allows users to input and check their health symptoms. The "Risk Assessment Tool" indicates if the app has a built-in tool to assess the risk level of a user's health condition based on the symptoms entered. Lastly, the "Integration with Healthcare Stations in Holy Sites" item details whether the app is connected to healthcare stations or medical services to ensure a rapid response in case of emergencies or health issues.

Based on our search, Asefny and Sehha health applications can be used by pilgrims during Hajj and Umrah. These applications, developed under the support of Saudi Arabian health authorities, serve as primary examples of digital health initiatives aimed at addressing the unique needs of pilgrims during these significant religious events.

#### Asefny App

The Asefny app primarily focuses on providing emergency assistance. It aids pilgrims, including those with disabilities, in emergencies by enabling them to report emergencies and send distress calls via the app to the Red Crescent. Further, the app allows the user to pinpoint their location and maintain a record of the user's medical history. It also provides information on the nearest hospital and pharmacy to the user. This app is especially effective for quick emergency

responses and is invaluable for location-based services in the densely populated areas of Hajj and Umrah. Despite its strengths in emergency response, Asefny does not offer broader healthcare management tools like symptom checking or comprehensive health risk assessments (Aljohani et al., 2022; Saudi Red Crescent Authority (SRCA). ; The Unified National Platform. Hajj and Umrah).

### Sehha App

The Sehha app, developed under the Saudi Arabian Ministry of Health's initiative, offers a broader range of services. It includes features for monitoring physical activities, managing diets, and sending reminders for medical checkups and appointments. Its primary function is to facilitate direct medical consultations through audio and video with registered health professionals. The use of AI in Sehha enhances its capabilities to provide general preventive healthcare advice and fitness tips. However, similar to Asefny, Sehha lacks the integration of immediate physical medical assistance and does not feature a symptom checker for instant health risk assessments (Aljohani et al., 2022; Ministry of Health; The Unified National Platform. Hajj and Umrah).

Table 1. Analysis finding of the content of each healthcare applications compared to the proposed health Application.

Application Name	Primary Function			Targeted User		Symptom Checker Tool	Risk Assessment Tool	Integration with Healthcare Stations in Holy Sites
	Emergency Assistance	Medical Consultation	Personalized Self-care Management	Pilgrims	Others			
Asefny	√			√	√			
Sehha		√		√	√			
Proposed Health App	√	√	√	√		√	√	√

## 2.2 Challenges in Existing Healthcare Applications

Based on a thorough comparative analysis of the most relevant health applications currently in use for Hajj and Umrah, our research has identified several challenges that need to be addressed. In developing the proposed health application, we aim to address these challenges effectively. Some of the key challenges identified by existing health apps are as follows:

1. No existing applications provide a symptom checker feature, which is crucial for initial health assessment and guiding pilgrims on the urgency of their health issues.
2. Both apps lack an immediate risk assessment tool. Such a feature is essential for quickly determining the severity of a pilgrim's health condition and deciding the necessary course of action.
3. No existing application directly connects medical service stations for rapid response. This integration is vital for ensuring quick medical intervention, especially in emergencies during Hajj and Umrah.
4. The existing apps focus on specific aspects of healthcare (emergency notifications and medical consultations); they may not adequately address non-emergency health concerns rapidly and provide comprehensive self-management.

## 3. Methods

### 3.1 Proposed Application Description

The massive gathering of pilgrims during Hajj and Umrah presents unique healthcare challenges, ranging from the management of common medical conditions to handling emergency situations in an overcrowded environment. The

existing digital health solutions, while beneficial, show gaps in offering comprehensive, integrated healthcare support tailored to the pilgrims need. Recognizing these challenges, our proposed mobile application was developed for Hajj and Umrah pilgrims to serve as a comprehensive health management tool tailored specifically for them. Its primary purpose is to enhance the safety and health management of the pilgrims by using AI technology to address common health concerns during the pilgrimage.

The first feature is a comprehensive symptom checker, which serves as the initial point of interaction for the user. This tool allows pilgrims to input any health symptoms they experience directly into the app. Upon inputting their symptoms, users might need to provide further information relevant to their symptoms, such as the level and location of pain. Then, they will be provided with a list of the most common health conditions associated with those symptoms. This will help in narrowing down the potential health concerns for further action. The final feature builds upon the previous functions by performing a risk assessment of the suggested health conditions. The app will evaluate the urgency and severity of the user's situation, and based on this assessment, it offers tailored advice on the next steps. This could range from self-care recommendations for less critical issues to facilitating virtual appointment bookings with medical professionals for intermediate concerns. In cases where the app determines a high level of risk, it will advise the user to seek urgent medical attention by providing the information of the nearest health station. The app will be connected to medical service stations at key Holy Sites (Grand Masjid, Mina, Arafat, and Muzdalifah), ensuring that the nearest station can provide immediate assistance to pilgrims in need. This connection guarantees a rapid response and efficient medical intervention. The approach in the proposed app will ensure that users receive appropriate advice corresponding to the level of care they need. The simulation of the app process is provided in the supplementary materials.

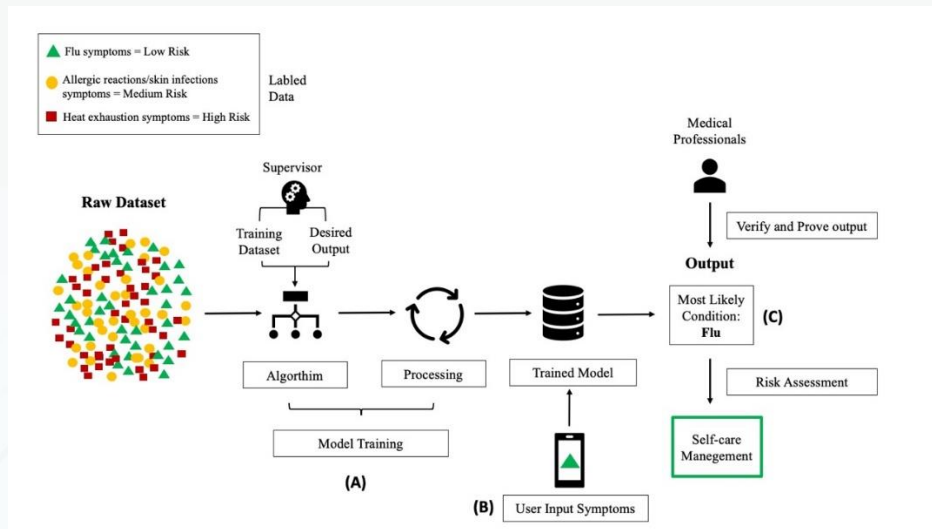
### 3.2 Development Method

The core AI technology selected for this app is Machine Learning (ML). The ML algorithms can analyze large datasets, recognize patterns, and make predictions or decisions based on data. Therefore, the algorithm for the proposed app will be designed and trained to process the input symptoms by pilgrims, identify potential health conditions, and predict the risk degree of the potential health conditions. The development of this algorithm will rely on a comprehensive raw dataset of symptoms collected from medical textbooks and guides, ensuring a thorough representation of symptoms associated with the most common health conditions that pilgrims might face.

The process will include the systematic labeling and processing of the collected symptoms data to create a machine-learning-compatible dataset. This dataset will categorize symptoms and link them to corresponding health conditions and risk levels in a format that can be easily interpreted by the algorithm. The algorithm (trained model) will then analyze the entered symptoms (input) and suggest common health conditions relevant to the pilgrimage setting (output). We will involve a medical staff in the decision-making process to verify and prove the output (most likely health conditions) generated by the trained model. Next, the algorithm (trained model) will determine the degree of risk associated based on the identified health condition. For each of the most common health conditions collected in the dataset, we will assign a risk level based on medical guidelines and input from healthcare professionals. The risk levels will be categorized as the following: "High" risk indicates that the pilgrim's health condition needs immediate medical attention. "Medium" risk level is defined as health conditions that are not immediately life-threatening or require emergency intervention but are significant enough to warrant medical attention beyond basic self-care management, while "Low" risk might suggest that self-care management is sufficient. Following the risk assessment, the app will generate tailored health advice and recommendations, providing a personalized next-step plan for the pilgrim. The generated health advice and



recommendations will be based on recent medical guidelines and input from healthcare staff. The process is shown in **Figure 2**.



**Figure 2.** (A) Train a supervised model using the Raw dataset. The model will learn to correlate specific combinations of features (symptoms) with the corresponding health conditions and risk levels. (B) Users input their symptoms into the app. (C) The trained model uses these features to predict the most likely health condition based on the input data and perform risk assessment based on the health condition. Medical professionals will verify and prove the output generated by the trained model.

In practical healthcare settings, especially during events like Hajj and Umrah, individuals may not always provide a complete set of symptoms due to various factors such as memory recall or time limits. Therefore, understanding the minimum amount of information needed to make an accurate diagnosis is important to optimize the AI algorithm in our proposed app during Hajj and Umrah settings.

In this study, we have designed an experimental approach to establish a precise threshold or percentage of symptom details required to predict health conditions in our proposed app accurately. By utilizing a current AI model like ChatGPT, we intend to systematically determine the minimum amount of symptom information necessary for effective diagnosis. This experiment involves providing ChatGPT with varying degrees of symptom details for a selected health condition, ranging from complete to partial lists, and assessing its diagnostic accuracy at each level. The outcome will be crucial in designing our app's algorithm, ensuring it can reliably predict health conditions even with limited symptom data, thus enhancing its practical utility in real-world scenarios.

In this experiment, a single health condition common during the pilgrimage (Heat Exhaustion) is selected, with its full list of symptoms sourced from medical textbooks (*Endurance Sports Medicine: A Clinical Guide*, 2016). The symptoms are categorized into five sets representing 100%, 80%, 60%, 40%, and 20% of the total symptom list, simulating varying levels of detail that a pilgrim might provide. The list of symptoms categorized into five sets is shown in Table 2.

In the first round, ChatGPT is provided with a complete list of symptoms (100%) for the Heat Exhaustion condition. Subsequently, we reduced the symptom detail provided to ChatGPT, and the process was repeated with 80%, 60%, 40%, and 20% of the symptoms list. In each round, we assessed the AI's proficiency in condition identification while decreasing levels of symptom detail. The identification is considered successful if ChatGPT correctly names the health condition. The threshold of symptom detail necessary for accurate identification is noted.

Table 2. The list of the Heat Exhaustion condition symptoms categorized into five sets.

Symptom Set Percentage	Symptoms Included
100%	Dizziness, Fatigue, Fainting, Nausea, Vomiting, Headache, Flushed Skin, Profuse Sweating, Cold Clammy Skin, Elevated Temperature
80%	Dizziness, Fatigue, Fainting, Nausea, Vomiting, Headache, Flushed Skin, Profuse Sweating
60%	Dizziness, Fatigue, Fainting, Nausea, Vomiting, Headache
40%	Dizziness, Fatigue, Fainting, Nausea
20%	Dizziness, Fatigue

## 5. Experimental Results

The experimental findings demonstrated a varying degree of diagnostic accuracy by ChatGPT in identifying health conditions based on different levels of symptom detail. At 100% symptom detail, including symptoms like dizziness, fatigue, and elevated temperature, the AI suggested conditions such as Heat Exhaustion/Stroke, Viral/Bacterial Infection, and Dehydration. When the symptom set was reduced to 80%, the AI's suggestions shifted to include Hypoglycemia and Anxiety/Panic Attacks, in addition to Heat Exhaustion/Stroke. At 60% symptom set, the AI suggested Migraine, Gastrointestinal Disorders, and Dehydration. With a further reduction to 40%, the AI identified Dehydration, Anemia, and Vestibular Disorders, and at 20% symptom detail, the suggestions included Anemia, Dehydration, and Sleep Disorders. Findings are shown in Table 3.

Table 3. Results Findings.

Percentage of Symptoms Provided To AI	Symptoms	Suggested Health Conditions Identified By the AI
100%	Dizziness, Fatigue, Fainting, Nausea, Vomiting, Headache, Flushed Skin, Profuse Sweating, Cold Clammy Skin, Elevated Temperature	Heat Exhaustion/Stroke, Viral/Bacterial Infection, Dehydration
80%	Dizziness, Fatigue, Fainting, Nausea, Vomiting, Headache, Flushed Skin, Profuse Sweating	Heat Exhaustion/Stroke, Hypoglycemia, Anxiety/Panic Attacks
60%	Dizziness, Fatigue, Fainting, Nausea, Vomiting, Headache	Migraine, Gastrointestinal Disorders, Dehydration
40%	Dizziness, Fatigue, Fainting, Nausea	Dehydration, Anemia, Vestibular Disorders
20%	Dizziness, Fatigue	Anemia, Dehydration, Sleep Disorders

## 5. Discussion:

This research establishes a foundation, informing our subsequent efforts to develop and refine the AI-integrated health app tailored specifically for Hajj and Umrah pilgrims. The next phase of our project is to develop and refine an advanced AI algorithm that is capable of analyzing symptoms, assessing health risks, and providing personalized healthcare recommendations. The algorithm will be trained using the prepared symptom dataset. During this phase, the algorithm will learn to correlate specific symptoms and symptom combinations with a specific health condition

A critical phase of our methodology will be the pilot testing of this newly developed algorithm. This phase is essential for assessing the practical functionality of the algorithm in real-world situations and understanding how it interacts with the different user inputs of Hajj and Umrah pilgrims. The medical staff will review and verify the accuracy of the output and health recommendations generated by the AI. This step is important for ensuring the validity of the output and the health recommendations provided to the users. After pilot testing, the algorithm will undergo a rigorous validation process to

ensure its accuracy and reliability. This process will involve using different types of user inputs to test the model's predictions and refine its decision-making capabilities. Finally, after development, testing, and validation, the ML algorithm will be integrated into the health app.

## 6. Conclusion:

Given the overcrowding nature of the Hajj and Umrah events, a transforming digital healthcare solution to address the health needs of the pilgrims is warranted. The analysis of existing healthcare applications for Hajj and Umrah has revealed the need for a more integrated, comprehensive solution that combines emergency response, symptom checking, risk assessment, and personalized healthcare advice. Therefore, we proposed developing a healthcare application integrated with AI and ML designed specifically for Hajj and Umrah pilgrims to fill the current gap between healthcare services and receivers.

## References

- Aldossari, M., Aljoudi, A., & Celentano, D. (2019). Health issues in the Hajj pilgrimage: a literature review. *East Mediterr Health J*, 25(10), 744-753. <https://doi.org/10.26719/2019.25.10.744>
- Aljohani, A., Nejaim, S., Khayyat, M., & Aboulola, O. (2022). E-government and logistical health services during Hajj season. *Bulletin of the National Research Centre*, 46(1). <https://doi.org/10.1186/s42269-022-00801-4>
- *Endurance Sports Medicine: A Clinical Guide*. (2016). (T. L. Miller, Ed.). Springer. <https://doi.org/10.1007/978-3-319-32982-6>
- Ministry of Hajj and Umrah. Retrieved December 2 from <https://www.haj.gov.sa/Home>
- Ministry of Health. Retrieved December, 2 from <https://www.moh.gov.sa/eServices/Pages/sehha-app.aspx>
- Saudi Red Crescent Authority (SRCA). . Retrieved December, 2 from <https://www.srca.org.sa/en/srca-services/>
- Statistics, G. A. f. (2019). Total number of Umrah performers and pilgrims for 1440/2019. Retrieved December, 2 from <https://www.stats.gov.sa/en/news/340>
- Statistics, G. A. f. (2022). Total number of Umrah performers and pilgrims for 1443 /2022. General Authority for Statistics. Retrieved December, 2 from <https://www.stats.gov.sa/en/news/463>
- Statistics, G. A. f. (2023). Total number of Umrah performers and pilgrims for 1444 /2023. Retrieved December, 2 from <https://www.stats.gov.sa/en/news/464>
- The Unified National Platform. Hajj and Umrah. Retrieved December, 2 from <https://www.my.gov.sa/wps/portal/snp/aboutksa/hajjandUmrah>

## Supplementary Materials

6:25 PM 47%

### Symptoms Checker

MUSCLE PAIN

DIZZINESS

RUNNY NOSE

DROWSINESS

SNEEZING

INCREASED SWEATING

TREMBLING

JOINT PAIN

HEADACHE

Shortness of Breath

Throat Pain

High Temperature

COUGH

NASAL CONGESTION

VOMITING

FATIGUE

[next step](#)

[Home](#) | [Calendar](#) | [Add](#) | [Notifications](#) | [Messages](#)

6:25 PM 47%

### Level of Pain

No Pain
  Mild Pain
  Moderate Pain
  Severe Pain
  Very Severe Pain
  Worst Pain Possible

### Location of Pain

### The Frequency of Pain

[next step](#)

[Home](#) | [Calendar](#) | [Add](#) | [Notifications](#) | [Messages](#)

6:25 PM 47%

### Most Likely Conditions

- Influenza
- Heat Stroke
- Stomach Flu

[next step](#)

[Home](#) | [Calendar](#) | [Add](#) | [Notifications](#) | [Messages](#)

6:25 PM 47%

### Medical Recommendation

Seek Immediate Medical Attention

Outpatient clinics building - ground floor.  
From Sunday until Thursday.  
8:00 AM - 3:30 PM.

[Get Location](#)

[Home](#) | [Calendar](#) | [Add](#) | [Notifications](#) | [Messages](#)

6:25 PM 47%

### Medical Recommendation

Virtual Healthcare Visit

Dec, 2023

Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

[Book an Appointment](#)

[Home](#) | [Calendar](#) | [Add](#) | [Notifications](#) | [Messages](#)

6:25 PM 47%

### Medical Recommendation

Self-Care Advice

**Methods to treat muscle and joint pain:**

- Take regular breaks during your walk to rest.
- Distribute your backpack weight evenly.
- Consider using a wheelchair or any mobility aid for long distance.
- Apply an ice pack to the affected area with an ice pack for about 15-20 minutes.

**Methods to treat dehydration and general fatigue:**

- Drink small amounts of water regularly and avoid sugary drinks. It is important to make sure that you drink enough water throughout the day.
- Move to an airflow source such as air conditioning or a fan.
- You should feel better after 10 minutes. If the symptoms persisted, seek a medical-care consultation.

**Methods to treat flu:**

- Drink plenty of fluids and warm liquids to prevent dehydration and ease congestion.
- Use over-the-counter pain relievers as directed.
- Use a humidifier or inhale steam from a hot shower to ease congestion and cough.

[Read More](#)

[Home](#) | [Calendar](#) | [Add](#) | [Notifications](#) | [Messages](#)



## A Review of Machine Learning Techniques to improve Hajj Healthcare

Hanan M. ALghamdi

Department of Computers, College of Engineering and Computers, Umm Al-Qura University

\*Corresponding author: E-mail (hmhghamdi@uqu.edu.sa)

### مراجعة تقنيات التعلم الآلي لتحسين الرعاية الصحية في الحج

حنان مسفر الغامدي

قسم الحاسبات، كلية الهندسة والحاسبات بالائفنفة، جامعة أم القرى

#### الملخص

تعتبر صحة الحجاج أثناء الحج ذات أهمية قصوى وتتطلب اهتمامًا دقيقًا. ونظراً لطبيعة الحج والعدد الكبير من الحجاج فيه، فإن هناك اهتمام بالغ بشأن انتقال الأمراض بين الحجاج. ولمعالجة هذه المشكلة بشكل فعال، من الضروري إجراء مراجعة شاملة للأبحاث الموجودة حول الأمراض المنتشرة أثناء الحج. يجدر الإشارة إلى أن خوارزميات التعلم الآلي توفر مساعدة قيمة في تحسين خدمات الرعاية الصحية أثناء الحج في المملكة العربية السعودية. تهدف هذه الورقة إلى استكشاف الاستخدام المحتمل للتعلم الآلي في الرعاية الصحية وتؤكد على أهمية تسخير قدراته بشكل كامل خلال موسم الحج. وتقدم نظرة عامة على أخطار الرعاية الصحية الشائعة المرتبطة بالحج وتقدم تصنيفًا لتقنيات الذكاء الاصطناعي التي يمكن أن تساعد في تقليل هذه المخاطر. بالإضافة إلى ذلك، فإن استخدام تقنيات الذكاء الاصطناعي مثل خوارزميات التعلم الآلي، وتحليلات البيانات، والنمذجة التنبؤية يمكن أن يعزز أنظمة مراقبة الأمراض ويسهل الكشف المبكر والاستجابة لتفشي الأمراض المحتملة. في الختام، من خلال إجراء مراجعة للأبحاث واستخدام نماذج التعلم الآلي، يمكننا الحصول على فهم أفضل لمخاطر الرعاية الصحية الشائعة المرتبطة بالحج. وهذا يمثل فرصة لتعزيز خدمات الرعاية الصحية خلال هذا الحدث الهام.

#### Abstract

The well-being of pilgrims during the Hajj is of utmost importance and warrants careful attention. Due to the nature of the Hajj pilgrimage and the large number of participants involved, there is a legitimate concern about the transmission of diseases among pilgrims. To effectively tackle this issue, conducting a comprehensive review of existing literature on disease transmission during the Hajj is crucial. Furthermore, the integration of Machine Learning (ML) algorithms can offer valuable assistance in enhancing healthcare services during the Hajj in Saudi Arabia. This paper aims to explore the current potential utilization of ML in healthcare, with a focus on its importance during the Hajj. It will provide an overview of common healthcare risks associated with the Hajj and present a taxonomy of Artificial Intelligent (AI) technologies that can help minimize these risks. Furthermore, the utilization of AI technologies, including machine learning algorithms, data analytics, and predictive modeling, can greatly enhance disease surveillance systems and enable early detection and response to potential outbreaks. In conclusion, by conducting a comprehensive literature review and employing ML

models, we can acquire a deeper understanding of the prevalent healthcare risks associated with Hajj. This offers a valuable opportunity to improve healthcare services during this significant event.

**Keywords:** Healthcare, Hajj, AI Technology, Machine Learning.

## 1. Introduction

Hajj is the annual pilgrimage to Mecca and is considered one of the largest gatherings of people in the world. While participating in this experience brings spiritual fulfillment to millions of Muslims, it also presents considerable health risks. The large number of pilgrims from various parts of the world increases the potential for rapid spread of infectious diseases. Additionally, the physical demands and crowded conditions during Hajj can lead to accidents and injuries. It is crucial for healthcare authorities to address these risks effectively in order to ensure the well-being and safety of all pilgrims.

Respiratory tract infections, including influenza and pneumonia, have been identified as the primary health risks during the Hajj pilgrimage, as referenced in [1]. Controlling well-known infections poses significant challenges for disease control, and the emergence of diseases like Middle East respiratory syndrome coronavirus (MERS-CoV) further complicates the situation. Respiratory infections accounted for the majority of reported infectious diseases, comprising 53.26% of the cases, followed by trauma at 24.40% according to study done in [2]. Additionally, there were reported cases of upper and lower respiratory infections, gastroenteritis, and skin and soft-tissue infections associated with diabetes. The respiratory system accounted for the majority (45.0%) of reported diseases, with upper respiratory tract infections (URIs) making up a significant portion (72.7%) of these cases [3]. Conditions related to the musculoskeletal system and connective tissue comprised 17.2% of diagnoses, including muscle strain (33.6%), joint and lower back pain (29.0%), and arthritis (16.8%) [3]. Skin and subcutaneous tissue diseases accounted for 10.5% of diagnoses, with dermatitis being the primary condition at 34.6% [3]. The concern was that diseases such as severe acute respiratory syndrome (SARS), avian influenza, haemorrhagic fever, and H1N1 could be brought into the Hajj by pilgrims, leading to local propagation and subsequent transmission to cities and countries worldwide [2], [4], [5]. This could potentially amplify and accelerate the global spread of the infection. Managing and addressing these evolving health risks poses further challenges for disease control efforts.

The utilization of AI applications has become increasingly necessary in the healthcare industry. These advanced applications play a critical and essential role in assisting medical professionals, including esteemed doctors, in making informed decisions [6], [7]. With their ability to thoroughly analyze large volumes of complex datasets, these applications provide doctors with the power to effectively identify anomalies, recognize patterns, and discover valuable trends [8]. Furthermore, the utilization of this advanced technology enables healthcare providers to mitigate the possibility of human errors. The integration of state-of-the-art AI techniques, especially Machine Learning (ML) models, has brought about a remarkable transformation and optimization in healthcare operations [9]. The integration of ML in the healthcare sector not only enables more accurate and efficient medical practices but also enhances the overall effectiveness of healthcare systems [10]. This seamless fusion empowers medical practitioners with fast computing capabilities, allowing them to handle complex tasks swiftly and accurately [7].

Among the fascinating innovations in healthcare technology, smart imaging stands out as a promising field, made possible only through ML. By employing ML algorithms, medical professionals can analyze imaging data with a level of proficiency comparable to highly skilled radiologists. This allows for the detection of abnormal skin patches, lesions,

tumors, and even brain bleeding [10]. Additionally, smart patient records play a pivotal role in modern healthcare practices by providing vital information on patients' medical histories and treatments received thus far. Improving and simplifying patient records can assist medical workers in anticipating potential issues, resolving present ones, and assessing specific situations. Predictive analytics, based on machine learning, has proven to be a valuable tool in the field of clinical trials [7]. By leveraging this technology, both time and financial resources can be saved, while ensuring accurate findings. The ability to analyze vast amounts of data enables specialists to detect potential flaws that may not be apparent at present but could have significant implications for our health and well-being. This enhanced monitoring capability ultimately improves the overall safety and effectiveness of clinical trials. Moreover, machine learning technologies can identify potential candidates for clinical trials, access their medical records, oversee the candidates' progress during the trial process, select the most suitable samples for testing, minimize errors related to data analysis, aid in determining optimal sample sizes, and fulfill various other functions[7].

To ensure the safety of Hajj pilgrims, it is crucial to address the limited knowledge and guidance regarding respiratory infections and recommended vaccinations. Providing comprehensive information about the potential risks associated with respiratory infections and emphasizing the importance of utilizing machine learning algorithms and applications in diagnosing, predicting, and prescribing appropriate medication for common health risks is of utmost importance. By leveraging these advanced technologies, healthcare professionals can enhance their ability to identify potential outbreaks, monitor disease patterns, and recommend preventive measures tailored to individual pilgrims' needs. This will not only contribute to a safer Hajj experience but also promote public health on a global scale.

The objective of this paper is to research the potential application of ML in healthcare, with a specific focus on its implementation during the Hajj pilgrimage. This research aims to provide a comprehensive understanding of ML's capabilities and how they can be effectively utilized to improve healthcare during this auspicious occasion. Additionally, the paper will examine the challenges and potential risks that pilgrims may face, ensuring a thorough analysis of both benefits and concerns surrounding ML implementation in this unique context. The structure of this paper is as follows: The second section will present a summary of prior studies pertaining to technologies and their utilization within the Hajj. Subsequently, in the third section, a concise explanation of the smart Hajj where the employed technology discussed. The fourth section will present challenging issues related to the review in an open manner. Finally, the fifth section will serve as the recommendations and conclusion of the paper.

## 2. Literature Review

The healthcare services industry has greatly benefited from the use of AI techniques, such as Machine Learning (ML) and Deep Learning (DL) algorithms. These advanced algorithms have demonstrated their effectiveness in analyzing extensive amounts of data, leading to the identification of patterns that play a crucial role in addressing health risks and enhancing patient care through accurate and timely diagnoses[7].

This capability enables healthcare professionals to make well-informed decisions regarding patient care based on more precise predictions. Based on an analytical study conducted from 2016 to 2020, researchers primarily focused on the field of artificial intelligence in the context of the Hajj and Umrah system. This area accounted for 24.2% of their overall research efforts[6]. The following sections investigate more in healthcare during Hajj and using ML for healthcare.

## 2.1 Healthcare during Hajj

The Ministry of Health (MoH)<sup>1</sup> in Saudi Arabia, in partnership with the World Health Organization, has implemented and advised a range of preventive health measures for pilgrims. These encompass vaccinations and various disease control strategies.

A comprehensive study comprising 280 pilgrims from 28 countries was conducted to examine the perception of health risks associated with the Hajj pilgrimage [11]. The findings of the study indicate a decrease in the awareness level among pilgrims regarding these risks. Consequently, it emphasizes the crucial need for comprehensive approach involves raising awareness, implementing surveillance systems, upholding hygiene standards, providing healthcare services, and promoting international collaboration [12]. At present, there is an absence of a cohesive health information system that establishes a connection with Hajj companies [13]. The development of a data-sharing platform or application for all stakeholders in the Hajj pilgrimage facilitates the gathering of crucial pre-Hajj information, including comprehensive medical records and vaccination details. Furthermore, it enables data collection during the pilgrimage for research purposes, health education programs, and the implementation of public health interventions. Access to accurate information about pilgrims' medical conditions enhances their experience by ensuring appropriate healthcare measures are in place and effectively managing potential health risks throughout the Hajj.

Based on a study involving employees from Hajj and Umrah companies [13], as well as the healthcare sector, valuable insights were obtained regarding the essential procedures required to ensure proper care for sick pilgrims. Most participants (66.7%) prioritize technological advancement for better quality and accuracy of services. A majority (83%) acknowledges the absence of a unified health application, while some are uncertain (16%). All participants confirm integration with the Ministry of Hajj and Umrah's electronic path.

Hajj pilgrims face several challenges, including limited access to necessary medications and language barriers [2]. Muslims from various nationalities come to Hajj and may not speak the local language fluently. As a result, they communicate in their respective languages. When searching for medication and health information, they often come across important pieces of information written in an unfamiliar language to them.

The emergency department, which operates during the Hajj pilgrimage, often faces significant challenges when attending to patients who arrive with limited or no knowledge of their medical background or treatment history [14]. In order to effectively tackle this issue and ensure efficient healthcare delivery, Nafea et al. [15] introduced an innovative health tracking framework that is based on Electronic Health Records (EHR). This framework aims to provide a comprehensive and easily accessible repository of patients' medical information, enabling healthcare professionals to make well-informed decisions and deliver personalized care during this critical period. EHR refers to a compilation of multiple electronic medical records generated by physicians, along with the personal health record created by the patient themselves.

At the primary healthcare facility's Emergency Department (ED) during the Hajj pilgrimage, numerous individuals sought medical attention. Many of these patients were discharged within 24 hours, particularly in the morning and afternoon periods [16]. It is noteworthy that both admitted and discharged cases received comparable levels of care. A significant number of visitors to the ED were discharged without needing additional treatment or referral to other medical facilities [16]. This showcases the Saudi government's commitment to providing excellent healthcare services and

<sup>1</sup> [https://www.moh.gov.sa/en/HealthAwareness/Pilgrims\\_Health/Pages/Guidelines-for-Hajj.aspx](https://www.moh.gov.sa/en/HealthAwareness/Pilgrims_Health/Pages/Guidelines-for-Hajj.aspx)



convenient access to hospitals for all Hajj pilgrims, regardless of the severity of their conditions. However, there is an ongoing discussion about the effect of patients with non-serious conditions on delays in ED patient flow.

Ensuring the well-being and safety of potential pilgrims during the Hajj is of paramount importance. With the growing number of applicants each year, it becomes crucial to implement an approach that assesses the ability of individuals to undertake this journey based on their health conditions[17]. Prioritizing those who are in good health will not only enhance their own experience but also contribute to a smoother and more organized pilgrimage overall.

According to the findings of study[2], pilgrims have identified heatstroke, vomiting, diarrhea, pre-existing health conditions, and epidemics as significant health risks. The presence of infectious diseases, such as respiratory and gastrointestinal infections, significantly impacts the Hajj health system and poses a threat to healthcare professionals and public health security[4], [16] There are various challenges associated with diagnosing, treating, and controlling the global spread of potentially drug-resistant pathogens[18]. Furthermore, overcrowding during mass gatherings amplifies the risk of transmitting respiratory pathogens such as rhinovirus, respiratory syncytial virus, Middle-East Respiratory Syndrome (MERS), other coronaviruses, influenza A H1N1, influenza B, and parainfluenza virus[3]–[5]. Agent-based modeling offers a valuable approach to anticipate potential disease spread scenarios within the Grand Mosque during Hajj [19]. By employing this method, researchers can simulate various situations and factors that influence the transmission of diseases.

## 2.2 Machine Learning for Healthcare

ML is a multifaceted field that encompasses an academic discipline as well as a collection of techniques. It empowers computers to perform complex tasks by utilizing principles from mathematics, statistics, and computer science. ML allows machines to learn from experience and make predictions or decisions without relying on explicit programming. This technology has had a revolutionary impact on healthcare, particularly in areas such as natural language processing (NLP), image recognition, recommendation systems. ML algorithms have the potential to greatly benefit Hajj in various areas. These include enhancing predictive capabilities, improving medical imaging diagnoses, enabling intelligent connectivity, and effectively managing records of patient data as shown in Figure 1 [6], [8], [10], [20].

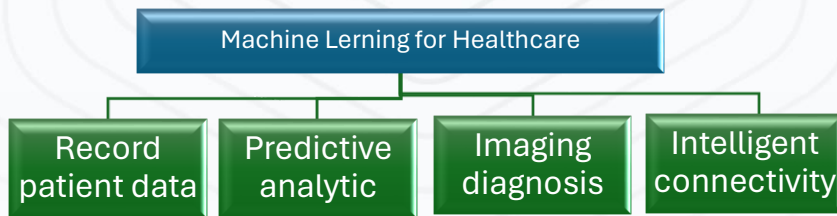


Figure 5 . Areas of ML algorithms that benefit Hajj.

Patient records are vital for healthcare. Simplifying and improving these records allows medical workers to predict and address issues more effectively[21], [22]. These records hold valuable information like diagnoses, health conditions, and insights into patients' well-being. The availability of medical records has led to the utilization of Machine Learning models, which can effectively analyze extensive data sets and identify patterns[7], [15]. This development has resulted in the implementation of smart patient records, EHRs, in the medical field. The utilization of these advanced records not only simplifies documentation processes but also equips healthcare professionals with invaluable insights to enhance their work.

The Smart Electronic Health Records (EHR) system integrates an advanced intelligent agent that creates a virtual depiction of an individual's health[23]. This interactive agent effectively communicates with healthcare professionals, offering comprehensive information and proactive resolutions for diagnosis and treatment determinations[24]. The Smart EHR system effectively handles healthcare data for multiple individuals by integrating a wide range of health information from different sources into a centralized Personal Record[22]. It collects data from various health information systems, wearable devices, and RFID tags[8]. Moreover, it accurately extracts relevant details from health documents and notifications received from local health apps. By adopting this comprehensive approach, the system enables remote patient monitoring and facilitates the consolidation of crucial information pertaining to individuals' health status, medical history, and treatments they undergo[25]. Undoubtedly, machine learning techniques have garnered considerable interest in the realm of disease prevention[7], [10]. These approaches hold great promise in streamlining testing procedures by improving the accuracy in identifying both the "where" and "who" for disease diagnosis[26]. Through the utilization of sophisticated algorithms and computational models, machine learning techniques can effectively analyze vast amounts of data. This analytical process enables the identification of patterns, risk factors, and predictive markers, which in turn enhance the precision and efficiency of diagnostic procedures. This is especially valuable in cases where disease diagnosis relies on imaging or signaling analysis.

Numerous studies have proposed models that effectively evaluate and classify patient symptoms in emergency departments (EDs)[27]–[29]. These ML-based models aim to monitor and predict patient admission after the ED triage[30], as well as predict emergency levels and categorize medical data[31]. One purpose is to track patients' visits to the EDs, document the treatment they receive, and determine their Length of Stay (LOS) in the hospital based on their individual treatment requirements [32]. Given that a patient's clinical history plays a vital role in making decisions during health emergencies or pandemics, it becomes crucial to process the data appropriately for classification and visualization using machine learning techniques. The integration of smart, portable screen devices in ED has greatly enhanced patient prioritization. With the aid of these devices, medical professionals can quickly assess, and address patients based on the severity of their conditions[27], [30] This technology allows for a more streamlined and effective triage process, ultimately leading to improved patient outcomes[27].

In addition to smart screen devices, the use of smart sensing devices has also become more prevalent in healthcare settings. These devices collect real-time patient data, providing valuable insights to medical professionals[8]. By continuously monitoring vital signs and other health indicators, these smart sensing devices enable early detection of potential issues, allowing for timely intervention and treatment. Wearable smart gadgets have emerged as a significant innovation in personal health monitoring[32]. These devices utilize machine learning algorithms to analyze the collected data and provide personalized insights to individuals[30]. By tracking various aspects of health, such as heart rate, sleep patterns, and exercise levels, these gadgets empower individuals to take proactive measures in managing their well-being. Furthermore, in emergency situations where immediate medical intervention is required, patients can now benefit from wearing smart wearable devices equipped with built-in sensors[32]. These sensors can accurately determine the patient's current location and generate a route to the nearest healthcare facility [6]. This not only ensures that patients receive prompt medical attention but also optimizes the allocation of resources within the healthcare system. Overall, the integration of smart, portable screen devices, smart sensing devices, and wearable smart gadgets in healthcare settings represents a significant advancement in patient care[8], [20] These technologies enable efficient patient prioritization, real-time monitoring of vital signs, and personalized health insights. Moreover, they contribute to timely

emergency medical interventions by providing accurate location information. Currently, there is ongoing development of an AI-driven chatbot that aims to provide medical advice and address common health-related inquiries for patients[33]–[35]. This chatbot will be accessible through smartphones and will have multilingual capabilities in order to cater to a wider range of users. Its purpose is to offer guidance on basic healthcare, ultimately enhancing the well-being and safety of individuals seeking medical information. By implementing natural language processing and translation capabilities, the chatbot will be able to accommodate the linguistic diversity of patients[36]. Additionally, machine learning algorithms will be incorporated to continually improve the chatbot's responses, efficiency, and customer service[10].

Given the growing demand for convenient and accessible healthcare services, AI-powered chatbots have significant potential for success[37]. They have the ability to revolutionize the way patients seek medical advice and information, offering reliable guidance anytime and anywhere[38]. Utilizing this chatbot as an effective tool can help engage with the target audience by providing valuable health-related content and generating leads through meaningful interactions.

In the healthcare system, the collection of vast amounts of data presents a unique opportunity for the development of powerful algorithms that leverage DL or ML methods. Of particular interest are medical images, which hold immense potential in providing accurate and comprehensive medical analysis[7], [28]. These images are acquired through various medical devices, including ultrasound machines and MRI scanners, among others. While each device can produce different types of images, all of these images have the potential to be automatically analyzed using machine learning algorithms in order to study and predict various diseases.

Absolutely, ML algorithms have demonstrated their immense value in the development of predictive models, particularly when it comes to utilizing medical image data[24]. These models offer profound insights into the advancement of diseases, treatment effectiveness, and the planning of surgical procedures for a wide range of medical conditions such as cancer, HIV[26], rhinovirus, respiratory syncytial virus, Middle-East Respiratory Syndrome (MERS)[39], [40], other coronaviruses, influenza A H1N1 [41], [42], influenza B[43], [44], parainfluenza virus[45], and skin diseases[46]–[52]. One significant advantage of ML algorithms in medical imaging is their ability to learn and improve over time. As more data is fed into the system, the algorithms can continuously update their knowledge and refine their predictions[7], [49], [50]. They can automatically learn features from images and classify them into different categories, such as normal or abnormal scans[28], [51], [52]. This iterative learning process enables them to become increasingly accurate and reliable in their analyses[49]. Moreover, ML algorithms can aid in improving the efficiency and speed of medical image analysis[50], [53]. By automating certain tasks that were traditionally performed manually by radiologists or other healthcare professionals, these algorithms can reduce the time required for diagnosis and treatment planning[24], [54]. This not only enhances patient care but also allows healthcare providers to optimize their resources and allocate them more efficiently.

### 3. Smart Hajj: Digital Transformation in Healthcare

In an effort to enhance healthcare services during the Hajj season, the Saudi Health Ministry has implemented the use of advanced "robot" technology for medical consultations<sup>1</sup>. This innovative approach is being applied at hospitals, medical centers in Mina, and even mobile medical units. As a result, individuals from all regions across the Kingdom can now have access to reliable medical consultations. Documentation of health practitioner licenses for healthcare providers,

<sup>1</sup> <https://ndu.mcit.gov.sa/sites/default/files/2021-09/Hajj-report-en.pdf>

trainees, and volunteers involves establishing a connection and integration with the Saudi Commission for Health Specialties in Hajj 1440. This ensures proper record-keeping and compliance with regulations in the healthcare sector. In addition, the utilization of electronic surveillance is being employed to ensure the preservation of environmental health. This approach encompasses various environmentally-friendly equipment and upgrades to further enhance sustainability measures. The Ministry of Hajj and Umrah has recently launched a mobile application called "YaHajj" which allows users to access information about the services provided by the ministry<sup>1</sup>. In addition, the application features a chat function that enables visitors to have their inquiries addressed promptly. The chat feature is designed in an interactive conversation format, ensuring efficient and effective communication with users without the need for human intervention. Recently, the Ministry of Health announced the activation of technology that utilizes artificial intelligence to analyze chest X-rays. This technology aims to assist pilgrims during the 2023 Hajj season<sup>2</sup>. The implementation of this technology has played a significant role in predicting diseases that may affect the lungs and heart. Consequently, it has enhanced the accuracy of doctors' evaluations and prioritized critical cases that require immediate medical attention in the emergency department.

#### 4. Using ML during Hajj: Discussion and Open Issues

The quality of healthcare services during the Hajj pilgrimage has improved. However, there are still many unresolved issues that can be addressed. ML has the potential to greatly enhance healthcare services during the Hajj pilgrimage. This review suggests several unresolved issues, including the need for an electronic platform and an awareness application for pilgrims. It also highlights the importance of enhancing virtual triage systems, improving specific Hajj chatbots or language translation tools, generating electronic medical records for pilgrims and utilizing AI-driven predictive analytics to identify potential health risks among pilgrims.

##### 4.1 Build an electronic platform and awareness application for pilgrim

It is strongly advised that the information system of the Saudi MoH undergo a thorough revamp to improve accessibility, specifically for individuals planning to embark on the Hajj pilgrimage. Aljohani, et al. [13] suggested establishing a unified electronic platform that can comprehensively manage the health services needs of the pilgrims. This platform should serve as a single portal where healthcare services can be integrated, thus enhancing awareness among pilgrims regarding disease prevention. The findings of the study done by Almehmadi et al. [11] shows an evident that there is a significant gap between the recommended preventive health measures and the actual adherence to these measures by pilgrims. To bridge this gap and enhance the dissemination of information on preventive health measures, it is crucial to implement a comprehensive enforcement application. This application should aim to ensure that all prospective pilgrims receive accurate and up-to-date information such as preventive measures, emergency contacts, and real-time updates on disease outbreaks. According to research findings, it has been established that such platform and application are associated with enhanced health awareness and behavioral changes among Hajj pilgrims [1], [2], [55], [56].

##### 4.2 Build virtual triage system

<sup>1</sup> <https://eumrasubs.com/Magazine/en/Home/BlogDetails/171>

<sup>2</sup> <https://www.moh.gov.sa/en/Ministry/MediaCenter/News/Pages/News-2023-06-30-001.aspx>

Virtual triage systems powered by AI algorithms could help prioritize patient cases based on severity or urgency[16]. These systems offer valuable assistance to healthcare professionals who may feel overwhelmed by the task of efficiently managing patient flow. By prioritizing urgent cases and minimizing waiting times for others, these systems prove to be highly effective tools in ensuring timely and appropriate care delivery. Machine Learning (ML) algorithms can be effectively employed to track the transmission of viral illnesses in the Emergency department and prioritize patients who require greater attention[32]. These algorithms have the capability to classify data into various categories, assisting in monitoring and managing the target audience. Pilgrim should consider partnering with reputable technology providers who prioritize data protection and have proven expertise in safeguarding sensitive information. By implementing stringent access controls, encrypting data transmission, and employing comprehensive data protection protocols, Pilgrim can mitigate potential privacy risks associated with the utilization of Virtual Triage systems. Additionally, educating users about the security measures in place and obtaining their informed consent can foster transparency and trust.

#### **4.3 Improve specific Hajj chatbots or language translation tools.**

Enhancing the functionality of Hajj chatbots and language translation tools can greatly facilitate efficient communication between pilgrims and medical personnel who may speak different languages. These advanced technologies can ensure accurate information exchange and improve patient care, considering the diverse backgrounds of participating Muslims from various countries. By developing a reliable and purpose-built medical chatbot specifically for pilgrims, it could serve as a seamless interface for both patients and healthcare providers to access relevant information[38]. During unprecedented situations like pandemics, the utilization of AI chatbots can offer a swift resolution to the surge in medical care demands[35]. These chatbots can be specifically tailored to cater to areas such as diagnosis, education, and healthcare. Moreover, AI-chatbot play a crucial role in generating leads and effectively disseminating information from reliable sources such as the Ministry of Health in Saudi Arabia and the Global Ministry of Health. Furthermore, these assistants can offer guidance on medical facilities and pharmacists in different languages, while also providing an e-Helpline equipped with translation services to overcome potential communication obstacles. Additionally, the use of trustworthy translation services and chatbot can greatly contribute to mitigating language barriers and invaluable asset to the pilgrims and the medical profession during Hajj.

#### **4.4 Generate Electronic Health Records for pilgrims.**

The instantaneous utilization of pilgrims' health information holds great significance for healthcare providers. It allows them to access a patient's complete health history, enabling swift and accurate treatment. The use of HER data has numerous benefits in medical research and healthcare. It allows for the analysis of disease genomics, speeds up clinical trial recruitment, and facilitates studies on lesser-known and emerging diseases[25]. Moreover, EHRs are expected to be crucial in collecting data for personalized treatment strategies and generating real-world evidence. EHR provide comprehensive information for machine learning approaches to predict patient outcomes. This includes diagnostic information, vital signals, lab tests, drug administration, and demographic information [57]. By thoroughly analyzing extensive EHR data, it is possible to effectively identify and prioritize individuals who possess optimal health conditions for participating in the pilgrimage[17].

This analysis can also assist in prioritizing patients within the ED, categorizing them into distinct groups based on the severity of their condition[31]. The adoption of EHR not only improves patient safety but also facilitates efficient coordination among healthcare professionals involved in the care of individual pilgrims. The utilization of Pilgrim medical health records and their subsequent dissemination to various authorities raises significant concerns regarding

privacy. Safeguarding this sensitive data and ensuring its ethical use are of utmost importance. It is imperative to implement robust measures to protect the confidentiality and integrity of such information, guaranteeing that it is handled in accordance with strict ethical guidelines.

#### 4.5 Use AI-driven predictive analytics to detect pilgrim potential health risk.

The utilization of AI-powered predictive analytics can be highly beneficial in detecting and addressing health risks among pilgrims, thus preventing emergencies or outbreaks from occurring. Through the analysis of diverse datasets, including medical images, EHR, and data from sensing devices used by pilgrims, this advanced technology enables doctors and other medical professionals to make well-informed decisions[7]. By identifying anomalies, patterns, and trends efficiently, it effectively mitigates the potential for human error while enhancing overall patient care. Moreover, the utilization of AI-driven predictive models can aid in the early detection and prevention of diseases during Hajj[58]. By analyzing a wide range of data, including environmental factors, individual health profiles, and disease patterns, machine learning algorithms can identify potential health risks and provide personalized recommendations for preventive measures. This proactive approach can significantly reduce the burden on healthcare services by preventing the onset of diseases and promoting a healthier pilgrimage experience. The storage and utilization of health data pertaining to Pilgrims for the purpose of predicting potential health risks gives rise to noteworthy privacy concerns. It is of paramount importance to diligently ascertain that this data is safeguarded with utmost security measures and handled in an ethical manner, instilling confidence in the individuals whose information is being utilized.

### 5. Conclusion

The primary objective of this research is to offer significant insights into the potential advantages and limitations of implementing machine learning algorithms in the healthcare services provided during Hajj. Its ultimate aim is to make a meaningful contribution to enhancing medical care and safeguarding the health and well-being of pilgrims. By thoroughly analyzing existing studies and exploring innovative solutions, this study endeavors to emphasize the importance of integrating machine learning technologies in optimizing healthcare delivery during one of the largest annual gatherings globally.

Saudi Arabia's remarkable success in organizing two consecutive Hajj seasons under exceptional circumstances has positioned the country as a leader in hosting this sacred pilgrimage. With valuable lessons learned from these experiences, Saudi Arabia is now seeking to capitalize on its achievements. The focus lies on creating an atmosphere of devotion and an environment of faith that facilitates pilgrims in efficiently performing their rituals. By utilizing innovative strategies and incorporating technology, Saudi Arabia aims to enhance the overall pilgrimage experience while upholding its commitment to providing a spiritually enriching journey for all pilgrims.

The recommendations put forth for the utilization of machine learning in healthcare services during the Hajj pilgrimage demonstrate immense potential in addressing longstanding unresolved issues. Through the establishment of an electronic platform and application, there is an opportunity to effectively raise awareness and mitigate health risks. Furthermore, by enhancing the virtual triage system and leveraging predictive analytics, it becomes possible to identify health risks at an early stage, thus facilitating prompt intervention. In addition, integrating smart Electronic Health Records (EHR) can prove to be a pivotal development in streamlining healthcare processes during the Hajj pilgrimage. This technology enables seamless access to crucial medical information, ensuring comprehensive and informed care delivery. Furthermore, by enhancing communication channels among healthcare providers through innovative methods

like telemedicine or secure messaging systems, collaborations can be fostered to improve coordination and facilitate efficient decision-making processes. In summary, the implementation of these machine learning advancements in healthcare services during the Hajj pilgrimage holds significant potential for enhancing the overall healthcare experience for pilgrims.

## References

- [1] A. S. Alqahtani, M. Alfelali, P. Arbon, R. Booy, and H. Rashid, "Burden of vaccine preventable diseases at large events," *Vaccine*, vol. 33, no. 48, pp. 6552–6563, 2015, doi: <https://doi.org/10.1016/j.vaccine.2015.09.076>.
- [2] H. Taibah, S. Arlikatti, S. A. Andrew, P. Maghelal, and B. DelGrosso, "Health information, attitudes and actions at religious venues: Evidence from hajj pilgrims," *Int. J. Disaster Risk Reduct.*, vol. 51, p. 101886, 2020, doi: [10.1016/j.ijdr.2020.101886](https://doi.org/10.1016/j.ijdr.2020.101886).
- [3] S. Yezli, Y. Yassin, A. Mushi, Y. Almuzaini, and A. Khan, "Pattern of utilization, disease presentation, and medication prescribing and dispensing at 51 primary healthcare centers during the Hajj mass gathering," *BMC Health Serv. Res.*, vol. 22, no. 1, pp. 1–10, 2022, doi: [10.1186/s12913-022-07507-3](https://doi.org/10.1186/s12913-022-07507-3).
- [4] Z. A. Memish et al., "Hajj: Infectious disease surveillance and control," *Lancet*, vol. 383, no. 9934, pp. 2073–2082, 2014, doi: [10.1016/S0140-6736\(14\)60381-0](https://doi.org/10.1016/S0140-6736(14)60381-0).
- [5] A. Shujaa and S. Alhamid, "Health response to Hajj mass gathering from emergency perspective, narrative review," *Turkish J. Emerg. Med.*, vol. 15, pp. 172–176, 2015.
- [6] M. K. Shambour and A. Gutub, "Progress of IoT Research Technologies and Applications Serving Hajj and Umrah," *Arab. J. Sci. Eng.*, no. 0123456789, 2021, doi: [10.1007/s13369-021-05838-7](https://doi.org/10.1007/s13369-021-05838-7).
- [7] N. Ghaffar Nia, E. Kaplanoglu, and A. Nasab, "Evaluation of artificial intelligence techniques in disease diagnosis and prediction," *Discov. Artif. Intell.* 2023 31, vol. 3, no. 1, pp. 1–14, Jan. 2023, doi: [10.1007/S44163-023-00049-5](https://doi.org/10.1007/S44163-023-00049-5).
- [8] A. J. Showail, "Solving Hajj and Umrah Challenges Using Information and Communication Technology: A Survey," *IEEE Access*, vol. 10, pp. 75404–75427, 2022, doi: [10.1109/ACCESS.2022.3190853](https://doi.org/10.1109/ACCESS.2022.3190853).
- [9] H. M. Alghamdi, "Unveiling Sentiments: A Comprehensive Analysis of Arabic Hajj-Related Tweets from 2017–2022 Utilizing Advanced AI Models," *Big Data Cogn. Comput.* 2024, Vol. 8, Page 5, vol. 8, no. 1, p. 5, Jan. 2024, doi: [10.3390/BDCC8010005](https://doi.org/10.3390/BDCC8010005).
- [10] M. Javaid, A. Haleem, R. Pratap Singh, R. Suman, and S. Rab, "Significance of machine learning in healthcare: Features, pillars and applications," *Int. J. Intell. Networks*, vol. 3, no. May, pp. 58–73, 2022, doi: [10.1016/j.ijin.2022.05.002](https://doi.org/10.1016/j.ijin.2022.05.002).
- [11] M. Almeahdi, G. Pescaroli, J. S. Alqahtani, and T. Oyelade, "Investigating health risk perceptions during the Hajj: Pre-Travel advice and adherence to preventive health measures," *Res. Artic. 1 African J. Respir. Med.*, vol. 16, no. 2, 2021.
- [12] A. S. Alqahtani, M. Tashani, A. E. Heywood, R. Booy, H. Rashid, and K. E. Wiley, "Exploring Australian Hajj Tour Operators' Knowledge and Practices Regarding Pilgrims' Health Risks: A Qualitative Study," *JMIR Public Heal. Surveill.*, vol. 5, no. 2, p. e10960, May 2019, doi: [10.2196/10960](https://doi.org/10.2196/10960).
- [13] A. Aljohani, S. Nejaim, M. Khayyat, and O. Aboulola, "E-government and logistical health services during Hajj season," *Bull. Natl. Res. Cent.*, vol. 46, no. 1, p. 112, 2022, doi: [10.1186/s42269-022-00801-4](https://doi.org/10.1186/s42269-022-00801-4).
- [14] S. Bangle and S. Kadam, "Real time tracking and EHR for pilgrim," *Proc. 2015 Int. Conf. Appl. Theor. Comput. Commun. Technol. iCATccT 2015*, pp. 116–120, Apr. 2016, doi: [10.1109/ICATCCT.2015.7456866](https://doi.org/10.1109/ICATCCT.2015.7456866).
- [15] I. Nafea, M. N. Bhairy, and Z. A. Zeidan, "Health tracking framework for Hajj pilgrims using electronic health records for Hajj," in *Proceedings - 2014 IEEE International Conference on Bioinformatics and Biomedicine, IEEE BIBM 2014*, Dec. 2014, pp. 605–607, doi: [10.1109/BIBM.2014.6999230](https://doi.org/10.1109/BIBM.2014.6999230).
- [16] A. A. Mirza, M. A. Alsakkaf, A. A. Mohammed, A. A. Mirza, and S. A. Elmorsy, "Patterns of emergency department visits during Hajj period: Towards healthcare optimization in view of Saudi Arabia's vision 2030," *Pakistan J. Med. Sci.*, vol. 35, no. 3, pp. 647–652, 2019, doi: [10.12669/pjms.35.3.611](https://doi.org/10.12669/pjms.35.3.611).

- [17] N. M. Huda and Albarda, "Design of Istitaah Classification System Based on Machine Learning Using Imbalanced Dataset," 2019 7th Int. Conf. Cyber IT Serv. Manag. CITSM 2019, Nov. 2019, doi: 10.1109/CITSM47753.2019.8965414.
- [18] I. D. Khan, S. A. Khan, B. Asima, S. B. Hussaini, M. Zakiuddin, and F. A. Faisal, "Morbidity and mortality amongst Indian Hajj pilgrims: A 3-year experience of Indian Hajj medical mission in mass-gathering medicine," *J. Infect. Public Health*, vol. 11, no. 2, pp. 165–170, 2018, doi: 10.1016/j.jiph.2017.06.004.
- [19] M. Tofighi et al., "Estimating social contacts in mass gatherings for disease outbreak prevention and management: case of Hajj pilgrimage," *Trop. Dis. Travel Med. Vaccines*, vol. 8, no. 1, pp. 1–11, Dec. 2022, doi: 10.1186/S40794-022-00177-3/FIGURES/6.
- [20] E. A. Felemban et al., "Digital Revolution for Hajj Crowd Management: A Technology Survey," *IEEE Access*, vol. 8, pp. 208583–208609, 2020, doi: 10.1109/ACCESS.2020.3037396.
- [21] J. A. Skorburg, "What Counts as 'Clinical Data' in Machine Learning Healthcare Applications?," *American Journal of Bioethics*, vol. 20, no. 11. Routledge, pp. 27–30, Nov. 01, 2020, doi: 10.1080/15265161.2020.1820107.
- [22] A. Fiske, D. Tigard, R. Müller, S. Haddadin, A. Buyx, and S. McLennan, "Embedded Ethics Could Help Implement the Pipeline Model Framework for Machine Learning Healthcare Applications," *American Journal of Bioethics*, vol. 20, no. 11. Routledge, pp. 32–35, Nov. 01, 2020, doi: 10.1080/15265161.2020.1820101.
- [23] L. D. Serbanati, "Health digital state and Smart EHR systems," *Informatics Med. Unlocked*, vol. 21, p. 100494, Jan. 2020, doi: 10.1016/j.imu.2020.100494.
- [24] S. Raul, S. Das, C. S. V. V. S. N. Murty, and B. S. Kiruthika Devi, "A Review on Intelligent Health Care System Using Learning Methods," *Adv. Transdiscipl. Eng.*, vol. 32, pp. 154–159, 2023, doi: 10.3233/ATDE221251.
- [25] S. Yang, P. Varghese, E. Stephenson, K. Tu, and J. Gronsbell, "Machine learning approaches for electronic health records phenotyping: a methodical review," *J. Am. Med. Informatics Assoc.*, vol. 30, no. 2, pp. 367–381, Jan. 2023, doi: 10.1093/JAMIA/OCAC216.
- [26] S. Weissman, X. Yang, J. Zhang, S. Chen, B. Olatosi, and X. Li, "Using a machine learning approach to explore predictors of healthcare visits as missed opportunities for HIV diagnosis," *AIDS*, vol. 35, no. 1, pp. 7–18, May 2021, doi: 10.1097/QAD.0000000000002735.
- [27] A. Vântu, A. Vasilescu, and A. Băicoianu, "Medical emergency department triage data processing using a machine-learning solution," *Heliyon*, vol. 9, no. 8, Aug. 2023, doi: 10.1016/j.heliyon.2023.e18402.
- [28] L. Wang and K. Zuo, "Medical Data Classification Assisted by Machine Learning Strategy," *Comput. Math. Methods Med.*, vol. 2022, 2022, doi: 10.1155/2022/9699612.
- [29] K. Bond and A. Sheta, "Medical Data Classification using Machine Learning Techniques," *Int. J. Comput. Appl.*, vol. 183, no. 6, pp. 1–8, Jun. 2021, doi: 10.5120/IJCA2021921339.
- [30] S. W. Choi, T. Ko, K. J. Hong, and K. H. Kim, "Machine learning-based prediction of korean triage and acuity scale level in emergency department patients," *Healthc. Inform. Res.*, vol. 25, no. 4, pp. 305–312, Oct. 2019, doi: 10.4258/hir.2019.25.4.305.
- [31] W. Liu, Z. Wang, N. Zeng, F. E. Alsaadi, and X. Liu, "A PSO-based deep learning approach to classifying patients from emergency departments," *Int. J. Mach. Learn. Cybern.*, vol. 12, no. 7, pp. 1939–1948, Jul. 2021, doi: 10.1007/S13042-021-01285-W/METRICS.
- [32] M. ; Kateb et al., "A Machine Learning Approach for Monitoring and Classifying Healthcare Data—A Case of Emergency Department of KSA Hospitals," *Int. J. Environ. Res. Public Health*, vol. 20, no. 6, p. 4794, Mar. 2023, doi: 10.3390/IJERPH20064794.
- [33] Z. Safi, A. Abd-Alrazaq, M. Khalifa, and M. Househ, "Technical aspects of developing chatbots for medical applications: Scoping review," *Journal of Medical Internet Research*, vol. 22, no. 12. JMIR Publications Inc., Dec. 01, 2020, doi: 10.2196/19127.
- [34] L. Athota, V. K. Shukla, N. Pandey, and A. Rana, "Chatbot for Healthcare System Using Artificial Intelligence," in *ICRITO 2020 - IEEE 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions)*, Jun. 2020, pp. 619–622, doi: 10.1109/ICRITO48877.2020.9197833.
- [35] J. C. L. Chow, L. Sanders, and K. Li, "Impact of ChatGPT on medical chatbots as a disruptive technology," *Front. Artif. Intell.*, vol. 6, 2023, doi: 10.3389/FRAI.2023.1166014.



- [36] H. Mendapara, S. Digole, M. Thakur, and A. Dange, "AI Based Healthcare Chatbot System by Using Natural Language Processing," *Int. J. Sci. Res. Eng. Dev.*, vol. 4, no. 2, pp. 89–96, 2021.
- [37] J. Lin et al., "Development of a practical training method for a healthcare artificial intelligence (AI) chatbot," *BMJ Innov.*, vol. 7, no. 2, pp. 441–444, Apr. 2021, doi: 10.1136/bmjinnov-2020-000530.
- [38] S. Badlani, T. Aditya, M. Dave, and S. Chaudhari, "Multilingual healthcare chatbot using machine learning," May 2021, doi: 10.1109/INCET51464.2021.9456304.
- [39] M. John and H. Shaiba, "Main factors influencing recovery in MERS Co-V patients using machine learning," *J. Infect. Public Health*, vol. 12, no. 5, p. 700, Sep. 2019, doi: 10.1016/J.JIPH.2019.03.020.
- [40] A. R. Zhang et al., "Ecology of Middle East respiratory syndrome coronavirus, 2012–2020: A machine learning modelling analysis," *Transbound. Emerg. Dis.*, vol. 69, no. 5, pp. e2122–e2131, Sep. 2022, doi: 10.1111/TBED.14548.
- [41] S. Inampudi, G. Johnson, J. Jhaveri, S. Niranjana, K. Chaurasia, and M. Dixit, "Machine Learning Based Prediction of H1N1 and Seasonal Flu Vaccination," *Commun. Comput. Inf. Sci.*, vol. 1367, pp. 139–150, 2021, doi: 10.1007/978-981-16-0401-0\_11/COVER.
- [42] E. Elbasi, A. Zreikat, S. Mathew, and A. E. Topcu, "Classification of influenza H1N1 and COVID-19 patient data using machine learning," 2021 44th Int. Conf. Telecommun. Signal Process. TSP 2021, pp. 278–282, Jul. 2021, doi: 10.1109/TSP52935.2021.9522591.
- [43] A. Tabarov et al., "Detection of A and B Influenza Viruses by Surface-Enhanced Raman Scattering Spectroscopy and Machine Learning," *Biosens. 2022*, Vol. 12, Page 1065, vol. 12, no. 12, p. 1065, Nov. 2022, doi: 10.3390/BIOS12121065.
- [44] Y. Xu and D. Wojtczak, "Dive into machine learning algorithms for influenza virus host prediction with hemagglutinin sequences," *Biosystems*, vol. 220, p. 104740, Oct. 2022, doi: 10.1016/J.BIOSYSTEMS.2022.104740.
- [45] S. Venkatraman et al., "Forecasting influenza activity using machine-learned mobility map," *Nat. Commun.* 2021 121, vol. 12, no. 1, pp. 1–12, Feb. 2021, doi: 10.1038/s41467-021-21018-5.
- [46] S. K. Bandyopadhyay, P. Bose, A. Bhaumik, and S. Poddar, "Machine Learning and Deep Learning Integration for Skin Diseases Prediction," *Int. J. Eng. Trends Technol.*, vol. 70, no. 2, pp. 11–18, Feb. 2022, doi: 10.14445/22315381/IJETT-V70I2P202.
- [47] J. Anitha, M. Kalaiarasu, N. S. Kumar, and G. R. Sundar, "Detection and classification of lung diseases using deep learning," *AIP Conf. Proc.*, vol. 12, no. 6, pp. 1096–1101, 2021, doi: 10.1063/5.0109980.
- [48] Mtende Mkandawire and Dr. Glorindal Selvam, "Prediction of Skin Diseases using Machine Learning Algorithms," *Int. J. Adv. Res. Sci. Commun. Technol.*, pp. 54–61, Oct. 2022, doi: 10.48175/ijarsct-7139.
- [49] S. S. Mohammed, J. M. Al-Tuwaijari, O. D. Falowo, J. A. Owolabi, Y. Oludoun, and S. Salim Mohammed, "Skin Disease Classification System Based on Machine Learning Technique: A Survey," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1076, no. 1, p. 012045, Feb. 2021, doi: 10.1088/1757-899X/1076/1/012045.
- [50] T. G. Debelee, "Skin Lesion Classification and Detection Using Machine Learning Techniques: A Systematic Review," *Diagnostics*, vol. 13, no. 19, Multidisciplinary Digital Publishing Institute, p. 3147, Oct. 07, 2023, doi: 10.3390/diagnostics13193147.
- [51] A. K. Verma, S. Pal, and S. Kumar, "Comparison of skin disease prediction by feature selection using ensemble data mining techniques," *Informatics Med. Unlocked*, vol. 16, p. 100202, Jan. 2019, doi: 10.1016/J.IMU.2019.100202.
- [52] M. Ahammed, M. Al Mamun, and M. S. Uddin, "A machine learning approach for skin disease detection and classification using image segmentation," *Healthc. Anal.*, vol. 2, p. 100122, Nov. 2022, doi: 10.1016/j.health.2022.100122.
- [53] J. Sun et al., "Machine Learning Methods in Skin Disease Recognition: A Systematic Review," *Process.* 2023, Vol. 11, Page 1003, vol. 11, no. 4, p. 1003, Mar. 2023, doi: 10.3390/PR11041003.
- [54] Z. Huang et al., "Intelligent System for Skin Disease Prediction using Machine Learning," *J. Phys. Conf. Ser.*, p. 12037, 2021, doi: 10.1088/1742-6596/1998/1/012037.
- [55] J. A. Al-Tawfiq, P. Gautret, S. Benkouiten, and Z. A. Memish, "Mass Gatherings and the Spread of Respiratory Infections. Lessons from the Hajj," *Ann. Am. Thorac. Soc.*, vol. 13, no. 6, pp. 759–765, Jun. 2016, doi: 10.1513/AnnalsATS.201511-772FR.

- [56] M. Alfelali and H. Rashid, "Prevalence of influenza at Hajj: is it correlated with vaccine uptake?," *Infect. Disord. Drug Targets*, vol. 14, no. 3, pp. 213–218, 2014, doi: 10.2174/1871526515999150320160055.
- [57] B. Joe, A. Mehra, I. Shin, and J. Hamm, "Machine Learning with Electronic Health Records is vulnerable to Backdoor Trigger Attacks," Jun. 2021, Accessed: Dec. 02, 2023. [Online]. Available: <http://arxiv.org/abs/2106.07925>.
- [58] M. K. Shambour, "Analyzing perceptions of a global event using CNN-LSTM deep learning approach: the case of Hajj 1442 (2021)," *PeerJ Comput. Sci.*, vol. 8, no. 2021, 2022, doi: 10.7717/PEERJ-CS.1087





## Measuring and Analyzing Stress and Strain of the Guests of Rahman during Hajj Rituals Using Advanced Technologies

Mazin I. Alshamrani\*<sup>1</sup>, Abdullah N. Hawsawi<sup>1</sup>, Ammar Alsaigh<sup>1</sup>, Tariq Alafifi<sup>2</sup>

1- The Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research at Umm Al-Qura University, 2- Al-Jammom Colledge, Computer Department, at Umm Al-Qura University.

\*Corresponding author: E-mail (dr.mazinalshamrani@gmail.com)

### قياس وتحليل التوتر والإجهاد لضيوف الرحمن في مناسك الحج باستخدام التقنيات المتقدمة

مازن إبراهيم الشمراي\*<sup>1</sup>، عبدالله نور هوساوي<sup>1</sup>، عمار الصايغ<sup>1</sup>، طارق العفيف<sup>2</sup>

1- معهد خادم الحرمين الشريفين لأبحاث الحج والعمرة بجامعة أم القرى، 2- الكلية الجامعية في الجموم - جامعة أم القرى

#### المخلص

تسعى هذه الدراسة لفهم الحالة المعنوية والجسدية لضيوف الرحمن خلال رحلة أداء مناسك الحج، حيث تهدف الدراسة إلى تعزيز التجربة الروحية من خلال تحليل العوامل المكانية والزمانية بشمولية والمؤثرة على مستوى الإجهاد والصحة النفسية والجسدية للحجاج خلال أداء النسك، وتعتمد الدراسة على نهج دقيق لتحليل حالة الحاج من خلال جمع وتحليل البيانات الحيوية والاستجابة الشعورية للحاج، وقامت الدراسة باستخدام أحد خوارزميات تعلم الآلة لتحليل البيانات وتحديد أوقات ومواقع الإجهاد والإرهاق الحرجة في رحلة الحج بناءً على نموذج لتتبع وقياس القراءات الحيوية لعينة الدراسة، وتشتمل منهجية البحث على ثلاث مراحل رئيسية وهي إنشاء إطار عمل قوي لجمع البيانات، وتجهيز واستخراج القراءات والتحليلات الأساسية من البيانات، وتطوير وتحقيق نموذج خاص بخوارزمية تعلم الآلة، وتساهم نتائج هذه الدراسة في فهم العوامل المكانية والزمانية المؤثرة على مستوى إجهاد الحاج خلال رحلة أداء النسك وربطها بعناصر الرحلة الأساسية، بالإضافة إلى ما تقدمه نتائج الدراسة من استيعاب لأبرز الحالات الجسدية والعاطفية خلال الرحلة والتي يمكن أن تساعد في التخطيط والشؤون الإدارية والتشغيلية للجهات المختصة بمنظومة خدمة ضيوف الرحمن وذلك لتطوير وتحسين تجربة الضيف ووضع معايير تتناسب مع الحالة الجسدية والشعورية للضيف الكريم، وقدمت الدراسة استخداماً لادوات عرض النتائج والأدوات التحليلية والتي ساعدت في عملية ربط تجربة الحاج وتحديد وتحسين نقاط الإجهاد الأعلى خلال رحلة الضيف.

الكلمات الدالة: التوتر، الإجهاد، العوامل الصحية والنفسية، الزحام، الحشود، الإجهاد الحراري، الإجهاد الجسدي

#### Abstract

This study seeks to understand the moral and physical state of the Guests of Rahman during their journey of performing the Hajj rituals. It aims to enhance the spiritual experience by thoroughly analyzing spatial and temporal factors that affect the level of stress and psychological and physical health of the pilgrims during their rituals. The study adopts a meticulous approach to analyze the pilgrim's condition through collecting and analyzing biometric data and the pilgrim's emotional response. It uses one of the machine learning algorithms to analyze the data and identify critical times and locations of stress and fatigue during the Hajj journey based on a model for tracking and measuring the biometric

readings of the study sample. The research methodology encompasses three main phases: establishing a robust framework for data collection, preparing and extracting the primary readings and analyses from the data, and developing and validating a specific model for the machine learning algorithm. The results of this study contribute to understanding the spatial and temporal factors affecting the pilgrim's stress level during the ritual journey and linking them to the fundamental elements of the journey. Additionally, the study's findings provide an understanding of the most prominent physical and emotional states during the journey, which can assist in planning and administrative and operational affairs for the authorities responsible for the service system of the Guests of Rahman. This is to develop and improve the guest experience and set standards that match the physical and emotional state of the honored guest. The study presented the use of tools for displaying results and analytical tools that helped in the process of linking the pilgrim's experience and identifying and improving the points of highest stress during the guest's journey.

**Keywords:** Pilgrim Stress, Biometric Analysis, Machine Learning in Pilgrimage, Spatial-Temporal Factors, Pilgrimage Experience Enhancement, Mental and Physical Well-being in Religious Tourism.

### 1. Introduction:

The Hajj, Islam's annual pilgrimage to its sacred sites, stands as one of the world's largest religious gatherings. It draws millions of Muslims from a mosaic of geographical and cultural backgrounds, creating a remarkable fusion of faith, culture, and geography. This extraordinary assembly, however, presents considerable challenges, particularly in safeguarding the health and well-being of these pilgrims, revered as the 'Guests of Rahman.' The pilgrimage transcends mere religious duty, embodying a profound spiritual journey, which demands an in-depth understanding of the myriad factors influencing the pilgrims' experiences. In this era of technological and analytical advancement, we find a unique opportunity to examine these influences meticulously. Our research delves deeply into the spatial and temporal dynamics that shape the pilgrim's journey, focusing on how location, time, and the stages of the pilgrimage intersect to affect their mental and physical health. As the Hajj is a fundamental aspect of the Islamic faith, it requires pilgrims to navigate through various sacred sites around Mecca, including the Masjid al-Haram. The growing number of pilgrims over the years has compounded issues like overcrowding, heat stress, and physical strain. This study aims to establish a scientific understanding of these challenges, thereby offering solutions to mitigate the physical and psychological pressures faced by the pilgrims.

Our approach is innovative, integrating the collection of biometric data and monitoring emotional states throughout the pilgrimage. We employ advanced machine learning algorithms to sift through this data, identifying critical instances and locations prone to stress and fatigue. This analysis is expected to shed light on aspects previously unexplored, offering fresh perspectives on the spatial and temporal facets of the Hajj. The methodology we've adopted streamlines the continuous collection of biometric data such as heart rate and body temperature, supplemented by surveys and observational methods to assess the pilgrims' emotional states. The application of machine learning to these large datasets enables us to extract significant insights into the pilgrims' health and well-being across various phases of their journey.

The implications of our findings are vast, extending to the future research and practical management of the Hajj. By pinpointing moments and locations of heightened stress and fatigue, we can guide decision-makers in developing targeted strategies to enhance the pilgrims' experience. This could involve designing smart, responsive infrastructure informed by real-time data, thus elevating the safety and overall satisfaction of the pilgrims. Furthermore, this study

contributes significantly to the broader realm of religious tourism. The insights gleaned here could be invaluable for managing other large-scale religious events worldwide. The integration of machine learning and data analytics paves the way for novel research and innovations in crowd management and urban planning tailored to religious gatherings.

## 2. Literature Review:

The well-being of pilgrims during religious journeys, particularly the Hajj pilgrimage, has been a subject of significant research interest. Studies have highlighted the challenges faced by healthcare professionals, such as nurses, in managing stress and burnout during the Hajj season [1]. Additionally, the prevalence of clinical respiratory infections and pneumonia during the Hajj pilgrimage has been documented, emphasizing the public health concerns and challenges for both Saudi and national authorities [2]. Furthermore, the impact of diabetes on pilgrims during the Hajj has been studied, indicating the potential for severe complications due to compromised immunity and other factors [3]. The literature also addresses the broader health issues and risks associated with the Hajj pilgrimage, particularly for pilgrims with pre-existing cardiac diseases, who are at high risk of physical stress leading to ischemia [4]. Moreover, the spatial and temporal effects of climatic factors on vegetation growth have been explored, indicating the relevance of spatial-temporal dynamics in understanding environmental influences [5]. Similarly, studies on the spatial-temporal variation of ischemic heart disease and tuberculosis highlight the importance of considering spatial and temporal factors in disease distribution and risk assessment [6][7].

In the context of pilgrimage experiences, the effects of spirituality on visitor behavior have been investigated, emphasizing the pursuit of hyper-meaningful travel associated with sacredness [8]. Furthermore, the identification of tourist routes through clustering techniques and the societal education media about Islamic law through web-based applications have been explored, indicating the diverse approaches to enhancing pilgrimage experiences and knowledge dissemination [9][10]. The utilization of advanced technologies, such as artificial intelligence (AI) and machine learning, has also been evident in various research domains. Studies have applied AI for predicting COVID-19 and its economic impact, emphasizing the significance of spatial and temporal data in understanding disease dynamics [11]. Additionally, the application of AI in traffic flow prediction and video person re-identification demonstrates the potential for AI to analyze spatial-temporal data for diverse purposes [12][13]. The health knowledge and attitudes of pilgrims, particularly in managing respiratory infections, have been investigated, highlighting the importance of health education and awareness during pilgrimages [14]. Moreover, the potential of dynamic factor modeling and tensor decomposition in capturing spatial and temporal variations has been explored, indicating the relevance of advanced analytical techniques in understanding complex spatiotemporal data [15][16]. Overall, the literature review underscores the multidisciplinary nature of research related to pilgrimage experiences, encompassing healthcare, environmental dynamics, spirituality, technology, and societal aspects. The synthesis of these diverse studies provides a comprehensive understanding of the factors influencing pilgrims' well-being and the potential interventions to enhance their spiritual journey experience.

## 3. Methodology:

Our research presents a meticulously crafted methodology, encompassing a wide array of data processes including collection, processing, and the creation of predictive models, all aimed at enhancing the understanding and management of large-scale events like religious pilgrimages. The methodology is systematically divided into three distinct yet interconnected phases, each critical to the study's success.

The initial phase is centered around establishing a robust framework for data collection. This involves the careful selection of suitable physiological signals and wearable sensors that seamlessly integrate with smartphone technology, ensuring real-time data capture and storage. The choice of wearable sensors is particularly crucial, with a focus on their compatibility with Android APIs to facilitate smooth integration with a custom-developed application. This stage is fundamental in laying the groundwork for the accurate collection of real-time physiological data from pilgrims during their activities. The selection of the study's sample was meticulously strategized, targeting individuals who exhibit a specific set of health and physical characteristics. We focused on participants with robust health, devoid of any acute or chronic medical conditions, and possessing an average build and moderate physical strength. This deliberate choice ensured that the subjects were physically capable of completing all the rituals of the Hajj pilgrimage without any health impediments.

Additionally, the participants were selected based on their age, falling into the middle-age category, which aligns with the demographic that typically performs the Hajj. A critical criterion for selection was their proficiency in handling technology, as the study required participants to interact with various technical devices and tools accurately and effectively. This proficiency was vital for the successful collection and recording of data throughout the study.

The study's sample size was limited to just two individuals. This decision was driven by several pragmatic considerations, including the limited availability of research tools, time constraints, and the extensive duration required for data collection. Furthermore, operational challenges such as the need to use devices in high-temperature conditions, substantial battery usage, and difficulties in recharging the devices under the conditions of the Hajj pilgrimage significantly influenced the decision to limit the sample size. This meticulous approach to sample selection, despite its limitations, was crucial to ensure the quality and reliability of the data collected under these challenging conditions.

Moving into the second phase, our focus shifts to data preprocessing and feature extraction. This is a vital step in transforming raw physiological data into a format conducive for analytical modeling. Our approach here includes leveraging mobile applications to collect comprehensive demographic data and annotations. This data encompasses a wide range of information, from personal details to medical history, as well as records of various activities, fatigue levels, and emotional states of the pilgrims. In addition, wearable sensors are employed to monitor multiple physiological parameters, with the data being stored in both local and cloud-based systems. The primary goal of this phase is to prepare the data meticulously for the final modeling stage. The third and concluding phase involves the development and validation of machine learning models. These models are designed to classify various aspects of the pilgrimage experience, including activities, fatigue levels, and emotional states. The accuracy and reliability of these models are rigorously evaluated through methods like 10-fold cross-validation. We recognize and address the challenges encountered, particularly in classifying emotional states, and propose potential improvements such as the adoption of ordinal data classes.

The study utilized two commercially available sensors, the Zephyr belt-type Bioharness and the Empatica E4 wristband, to collect subjects' physiological signals. The Zephyr Bioharness measures ECG, skin temperature, heart rate variability, respiration rate, and body motion, while the Empatica E4 wristband measures skin temperature, blood volume pulse (BVP), and electrodermal activity (EDA). The Zephyr Bioharness provides respiration rate data but requires the user to wear it on a bare chest for accurate readings. The Empatica E4 wristband uses an infrared thermopile sensor to measure skin temperature with an accuracy of  $\pm 0.2^{\circ}\text{C}$  within the range of  $36\text{--}39^{\circ}\text{C}$ . These sensors were chosen for their ability to monitor a broad range of physiological signals and support continuous and real-time monitoring. The Zephyr Bioharness

provides respiration rate data, while the Empatica E4 wristband measures skin temperature, BVP, EDA, and heart rate. The data collected from these sensors was stored in the phone's external storage as a comma-separated value (CSV) file and in a Room MySQL database in the mobile's internal storage. Additionally, a copy of the collected data was sent to Firebase, a cloud storage, whenever there was internet connectivity. In terms of validity and reliability, the study provided statistical summaries of the physiological data collected using the Empatica E4 wristband and the Zephyr Bioharness belt, demonstrating the reliability and validity of the sensors in capturing these vital signs. The study also discussed the limitations and potential biases of the sensors, such as data noise and missing data points, and proposed methods for addressing these issues, such as the use of the last observation carried forward (LOCF) method for missing values replacement. Overall, the study's selection of the Zephyr Bioharness belt and the Empatica E4 wristband, along with the methods used for data collection and storage, demonstrates a comprehensive approach to measuring vital signs with a focus on reliability and validity.

The study discusses the development of a real-time crowd management system for the Hajj pilgrimage using wearable physiological sensors, mobile technology, and artificial intelligence. It aims to understand the impact of stress, strain, and various physical and psychological factors on pilgrims' well-being. The research utilizes machine learning models for emotional classification and fatigue detection based on physiological signals. The study also proposed a comprehensive framework for automating crowd management, addressing the complexities of Hajj rituals and pilgrims' physical and psychological status. The research aims to enhance safety and well-being during mass gatherings, particularly in the context of the Hajj pilgrimage. The study's findings contribute to the development of innovative approaches for managing large crowds during mass gatherings, providing valuable insights into the potential applications of wearable sensors and artificial intelligence in this context. In summary, our paper delineates a holistic and structured methodology that integrates wearable physiological sensors, mobile technology, and machine learning. From the initial stages of data collection to the development of sophisticated analytical models, our methodology aims to gather, process, and interpret high-quality physiological data efficiently. This comprehensive approach is instrumental in enhancing the management and understanding of crowd dynamics during significant events such as religious pilgrimages, contributing valuable insights to the field.

#### 4. Results:

The demographic profile of the participants in this study presents a fascinating snapshot, offering a deeper understanding of the cohort under examination. Aged between 40 and 45 years, the participants are exclusively male and possess Saudi nationality, providing a culturally specific context to the study. Educationally, they represent a highly educated demographic, with academic credentials ranging from Bachelor's degrees to Master's degrees. This reflects a group with a substantial level of academic and professional expertise, particularly as they are engaged in roles as researchers or business developers. Furthermore, their health status is described as good, although they are not particularly inclined towards athletic activities. This aspect might offer interesting insights when correlating health with lifestyle choices. Socially, all the participants are married, which could provide an additional layer of social context in the analysis of the data. This demographic composition paints a picture of a specific, well-defined group, offering a rich field for data interpretation and analysis. Understanding these characteristics is crucial, as it helps in tailoring the study's insights to similar populations and in drawing more nuanced comparisons with other research that might involve different demographic groups. The specificity of this sample provides a unique opportunity to delve into the experiences and perspectives of this particular segment of the Saudi population. The results of the study are encapsulated in a series of

figures, each illustrating crucial aspects of the pilgrims' experiences during the Hajj. These figures effectively represent the emotional moods, levels of physical fatigue, and engagement in various Hajj activities as recorded and analyzed through the data collection process.

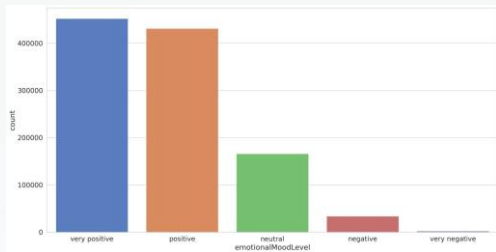


Figure 1: Emotional Mood Levels

Figure 1 presents a bar chart showcasing the distribution of different emotional mood levels among participants. The x-axis of the chart, labeled "emotionalMoodLevel," categorizes moods into five distinct levels: "very positive," "positive," "neutral," "negative," and "very negative." Correspondingly, the y-axis represents the count of records for each mood level. The chart reveals a predominant inclination towards positive emotional states, with the "very positive" mood level (depicted in blue) registering the highest count. This is followed by the "positive" mood level in orange. The "neutral" mood (green), while lower than the positive states, still shows a significant count. In contrast, the "negative" and "very negative" mood levels (red and purple, respectively) are substantially less frequent, suggesting a general trend of positive emotional experiences among the pilgrims during the Hajj.

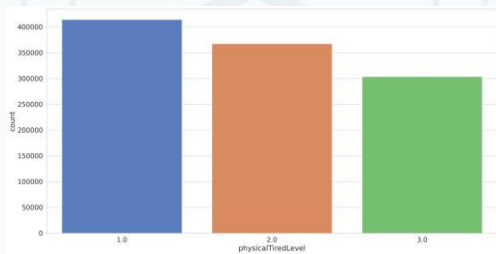


Figure 2: Physical Fatigue Levels

Figure 2 illustrates the range of physical fatigue levels experienced by participants. The x-axis, labeled "physicalTiredLevel," spans levels from 1.0 (No Fatigue) to 3.0, with no entries for levels 4.0 and 5.0 (the worst fatigue). This indicates an absence of extreme fatigue reports. The y-axis denotes the count for each fatigue level. The blue bar, representing "No Fatigue," emerges as the most common state, while the orange and green bars correspond to moderate (level 2.0) and more significant (level 3.0) fatigue levels, respectively. This distribution underscores that, although fatigue was experienced, it did not escalate to the most severe levels during the Hajj, according to the study's data.

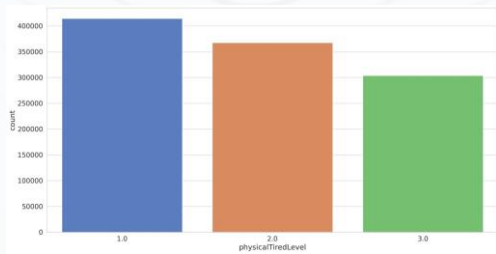


Figure 3: Engagement in Hajj Activities



Figure 3 displays a multi-colored bar chart detailing the participation in different acts or days of Hajj, referred to as "rukun." Each bar, distinctively colored, represents a specific Hajj activity or day. The "Day11\_MenaJamarat" activity, shown in pink, records the highest count, indicating it as the most prevalent or recorded activity. This is followed by "Hajj\_TawafOne" in light orange, and other activities in varying counts and colors, indicating lesser engagement. The chart's progression from left to right exhibits a decrease in the count of records for each subsequent activity or day, with "Hajj\_TawafTwo" having the lowest count. This data is insightful for understanding the frequency and duration of these activities during the Hajj. The methodology employed for conducting a comprehensive location analysis of participants during the Hajj rituals incorporated an advanced blend of geospatial data collection and sophisticated data visualization techniques. This approach was pivotal in deciphering the spatial dynamics of the pilgrimage, providing a detailed understanding of participant distribution and movement patterns as shown in **Figure 4**. Geospatial Data Acquisition The cornerstone of this methodology was the strategic collection of geospatial data. This task was accomplished through a custom-developed smartphone application, specifically designed to capture precise latitude and longitude coordinates of participants during various stages of the Hajj rituals. The application's capability to accurately record geographical data points in real-time was crucial in constructing a dataset rich in spatial details. Extensive Data Processing and Visualization The collected dataset, comprising nearly two million data points, represented a significant volume of spatial information that required careful and intricate processing. The methodology harnessed the power of Python, a language renowned for its efficacy in data analysis, along with its specialized libraries. Pandas, a library adept at data manipulation, and Geopandas, an extension tailored for geospatial data, were employed to organize and process the vast dataset effectively.

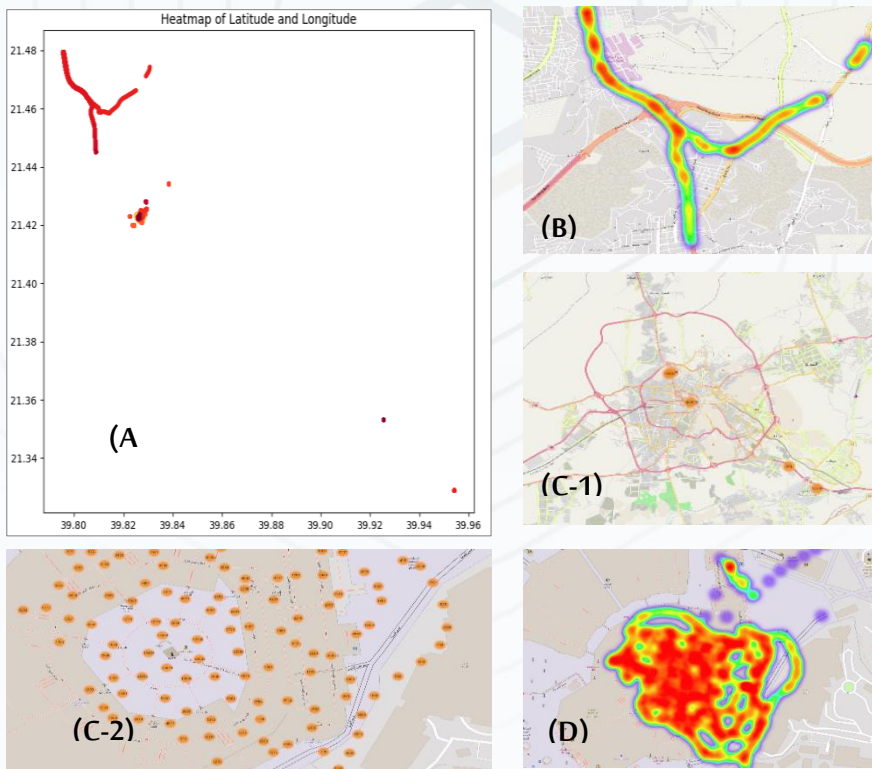


Figure 4: Overall Heatmap

The methodology employed for conducting a comprehensive location analysis of participants during the Hajj rituals incorporated an advanced blend of geospatial data collection and sophisticated data visualization techniques. This approach was pivotal in deciphering the spatial dynamics of the pilgrimage, providing a detailed understanding of participant distribution and movement patterns as shown in **Figure 4**.

**Geospatial Data Acquisition** The cornerstone of this methodology was the strategic collection of geospatial data. This task was accomplished through a custom-developed smartphone application, specifically designed to capture precise latitude and longitude coordinates of participants during various stages of the Hajj rituals. The application's capability to accurately record geographical data points in real-time was crucial in constructing a dataset rich in spatial details.

**Extensive Data Processing and Visualization** The collected dataset, comprising nearly two million data points, represented a significant volume of spatial information that required careful and intricate processing. The methodology harnessed the power of Python, a language renowned for its efficacy in data analysis, along with its specialized libraries. Pandas, a library adept at data manipulation, and Geopandas, an extension tailored for geospatial data, were employed to organize and process the vast dataset effectively.

For the visualization of this processed data, the methodology utilized matplotlib, a versatile Python library. This library facilitated the creation of detailed heatmaps, a form of data visualization that uses color-coding to represent different values. These heatmaps were instrumental in illustrating the density and clustering of participants across various pilgrimage locations and activities.

**Insightful Heatmap Generation** The heatmaps generated from this process were not merely graphical representations but insightful analytical tools. They provided an intuitive visualization of how participants were distributed and clustered in different areas during the Hajj. These visual insights were crucial in identifying areas of high density, potential congestion points, and the overall movement flow of the pilgrims.

**Methodological Implications and Applications** This refined methodology for location analysis and heatmap generation is noteworthy for its innovative application of technology in religious studies. The insights gleaned from the heatmaps have significant implications for improving crowd management strategies and enhancing the safety measures during the Hajj. By understanding the spatial behavior of participants, organizers and authorities can make data-driven decisions to optimize the pilgrimage experience.

In Figures 4 – (A) and (B), the heatmaps, enriched with 2 million data records, offer a sweeping overview of spatial data distribution during the Hajj. These visualizations are pivotal for pinpointing general trends, areas of concentration, and outliers, thereby providing a broad perspective on movement patterns and crowd behavior.

Figure (B) presents a pronounced heatmap to showcase distribution details, while figure (A), a more zoomed-out version, traces the data paths along Makkah's roads leading to Al Haram, offering insights into the directional flow of pilgrims. This wide-angle view aids in understanding key aspects such as entry points, traffic flow, and the overall routes taken by participants, proving invaluable for urban planning and event management. Figure (D) takes a different approach, zooming into the Haram area.

This localized heatmap delivers a granular look at spatial dynamics around the holy mosque, revealing insights into crowd congestion and movement patterns. This focused view is crucial for deciphering crowd behavior during pivotal moments of the pilgrimage. Graphs (C-1 and C-2), rather than relying on color hues, employ a geo-points visualization to represent data within the Haram area. This method, adept at handling the challenge of visualizing two million data points, offers a detailed look at specific locations, highlighting key sites, gathering points, and areas of varying activity.

Collectively, these visual tools each fulfill a unique role, enhancing our understanding of the Hajj dynamics. Together, they form a comprehensive analysis, bolstering the credibility of this study's findings in exploring the relationship between effort and satisfaction during the pilgrimage.

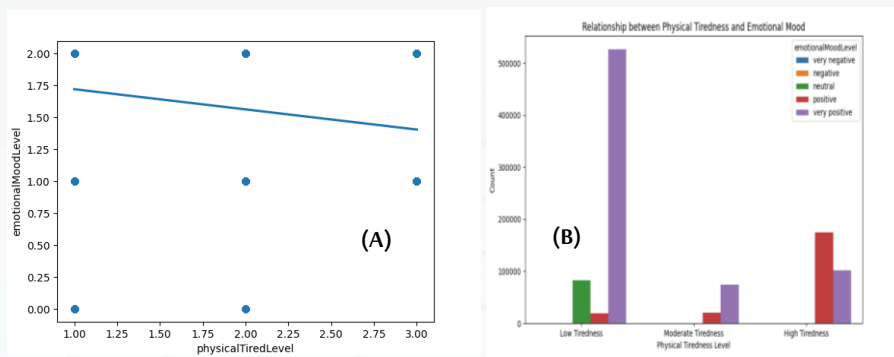


Figure 5: Enhanced Correlation Analysis between Physical and Emotional States in Pilgrimage Participants

This study delved into the intricate relationship between the physical states and emotional well-being of participants during the Hajj pilgrimage. Our investigation centered on correlating the physical fatigue levels, as indicated in the "physicalTiredLevel" column, with the emotional mood states, delineated in the "emotionalMoodLevel" column, see Figure 5 (A). A key challenge in this analysis was addressing the constraints posed by the categorical nature of the emotional mood data, which comprised five distinct categories: "very positive", "positive", "neutral", "negative," and "very negative." While this classification scheme captured a broad spectrum of emotional states, it also introduced an element of subjectivity, potentially limiting the ability to fully represent the complex tapestry of human emotions.

Despite these categorical constraints, our correlation analysis, leveraging robust statistical methodologies and comprehensive visualizations, unearthed significant insights. It is imperative to approach the interpretation of these findings with an understanding that the emotional mood categories might have somewhat simplified the rich and varied emotional experiences of the participants. Notably, the analysis suggested a discernible pattern: higher levels of physical exertion often correlated with more positive emotional states, and conversely, lower physical effort tended to align with less positive emotional moods, see figure-5 (B). In prospective iterations of this research, it would be beneficial to adopt a more refined emotional classification system, one that can more accurately and comprehensively encapsulate the diverse emotional experiences of individuals. Such an enhancement would allow for a deeper and more nuanced exploration of the emotional landscape experienced by participants. Furthermore, an examination of the role of contextual and situational factors in shaping emotional responses would offer additional layers of understanding. This could significantly enrich our comprehension of the complex interplay between physical exertion and emotional states, particularly in the unique context of religious pilgrimages. The findings from this enhanced correlation analysis not only contribute to the academic discourse on the interrelation between physical and emotional states during significant events like the Hajj but also provide valuable insights for organizers and planners. Understanding these dynamics is essential for creating environments and schedules that promote both physical and emotional well-being, thereby enhancing the overall experience of the pilgrims. These figures collectively provide a comprehensive view of the pilgrims' experiences during the Hajj. Figure 1 highlights the predominance of positive emotional states, Figure 2 indicates the range but not extremity of physical fatigue, and Figure 3 maps out the frequency of engagement in different Hajj activities. Together, they paint a detailed picture of the pilgrims' journey, offering valuable insights for future planning and management of

the Hajj pilgrimage. In this study, we employed a comprehensive methodology and sophisticated algorithms for data visualization and analysis to examine the dynamics of the Hajj pilgrimage. Our approach was twofold: first, to explore the relationship between the physical effort of pilgrims and their emotional states, and second, to map their spatial distribution throughout this significant event.

**Effort vs Emotion Visualization** Our initial focus was on understanding how physical tiredness correlates with emotional mood levels. We began by importing our dataset, 'limited\_cleaned\_data.csv', into a Pandas DataFrame. We then categorized the numerical tiredness data into descriptive labels - 'Low Tiredness', 'Moderate Tiredness', and 'High Tiredness'. This categorization was integral to our analysis, as it allowed us to better interpret the data.

We utilized the Seaborn and Matplotlib libraries to craft a bar plot, which visually represented the relationship between the 'TirednessCategory' and 'emotionalMoodLevel'. By setting specific orders for tiredness levels and emotional mood levels, we were able to generate a clear and interpretable graph. The plot was further refined with well-defined labels and a title, and finally displayed, offering a valuable visual representation of emotional states across different levels of physical tiredness.

**Heatmap and Geolocation Visualization** The second aspect of our methodology involved the creation of a heatmap to visualize the vast array of data points - a total of 2 million records. We constructed a GeoDataFrame using the GeoPandas library, converting latitude and longitude information into point geometries. This step was crucial in enabling us to visualize the data spatially. Using both Matplotlib and GeoPandas, we created a heatmap that displayed the geographical distribution of participants. The choice of color map and the size of the markers were carefully considered to enhance the clarity and readability of the visualization. The heatmap was then adorned with a title and displayed, revealing the density and clustering of participants in various regions. Overall, our methodologies in visualizing both the relationship between effort and emotions, and the spatial distribution of participants, provided us with a holistic view of the Hajj pilgrimage. The bar plots offered deep insights into the emotional landscape of the pilgrims against their physical exertions, while the heatmaps shed light on their movement patterns and congregations. These visualizations not only enhanced our understanding of the pilgrimage experience but also showcased the power of combining statistical analysis with advanced data visualization techniques.

**Pseudocodes:**

---

**Algorithm 1** Loading Data and Creating Bar Plot

---

```

1: df ← pd.read_csv('limited_cleaned_data.csv')
2: tiredness_mapping ← {1: 'Low Tiredness', 2: 'Moderate Tiredness', 3: 'High Tiredness'}
3: df['TirednessCategory'] ← df['NumericalTiredness'].map(tiredness_mapping)
4: plt.figure()
5: sns.countplot(data=df, x='TirednessCategory', hue='emotionalMoodLevel', order=['LT', 'MT', 'HT'], hue_order=...)
6: plt.xlabel('Physical Tiredness Levels')
7: plt.ylabel('Count')
8: plt.title('Relationship between Physical Tiredness and Emotional Mood')
9: plt.show()

```

---



---

**Algorithm 2** Loading Data and Creating Heatmap

---

```

1: df ← pd.read_csv('limited_cleaned_data.csv')
2: gdf ← GeoPandas.GeoDataFrame()
3: gdf['geometry'] ← df.apply(lambda row: Point(row['longitude'], row['latitude']), axis=1)
4: gdf ← GeoPandas.GeoDataFrame({'geometry': df.apply(lambda row: Point(row['longitude'], row['latitude']), axis=1)})
5: plt.figure()
6: gdf.plot(cmap='YlOrRd', markersize=10)
7: plt.title('Geographical Distribution Heatmap')
8: plt.show()

```

---

---

**Algorithm 3** Interactive Map Algorithm

---

```
1:  $df \leftarrow \text{read\_csv}('limited\_cleaned\_data.csv')$ 
2:  $map\_center \leftarrow \text{calculate\_map\_center}(df['latitude'], df['longitude'])$ 
3:  $mymap \leftarrow \text{create\_folium\_map}(map\_center, \text{zoom\_start} = 12)$ 
4:  $marker\_cluster \leftarrow \text{create\_marker\_cluster}()$ 
5: for point in  $df.iterrows()$  do
6:      $\text{add\_marker\_to\_cluster}(marker\_cluster, \text{point}['latitude'], \text{point}['longitude'])$ 
7: end for
8:  $\text{save\_map\_as\_html}(mymap, "map\_with\_clusters.html")$ 
```

---

## 5. Discussion:

The findings of this research, particularly through the careful creation of bar charts that illustrate the emotional mood levels, physical tiredness, and the array of activities partaken by participants during the Hajj, have significantly deepened our understanding of the pilgrimage experience. The visualizations, underpinned by solid data, reveal a largely positive emotional landscape among the pilgrims, paralleled with manageable levels of physical fatigue. This trend points to an overwhelmingly positive experience of the Hajj, indicating that, despite its inherent challenges, it is predominantly seen as a fulfilling and spiritually enriching journey by those who undertake it. Furthermore, the intricate analysis of the various activities integral to the Hajj and the frequency of participants' engagement in these rituals provides a thorough view of the pilgrims' involvement. This dimension of the study not only highlights the extent of their participation but also sheds light on the varied nature of their experiences. The depth of this data is particularly noteworthy, as it moves beyond basic numerical analysis into a richer, qualitative exploration, vividly capturing the essence of the pilgrims' journey through the sacred rites of the Hajj. This nuanced comprehension is vital, as it delves deeper than mere quantitative metrics, exploring the emotional and physical experiences of individuals within a unique spiritual context. Hence, the study's conclusions contribute not just to scholarly discussions on religious pilgrimages but also offer actionable insights for event organizers and authorities involved in planning and overseeing such large-scale events. The correlation between positive emotional experiences and manageable physical strain highlights the effectiveness of existing organizational strategies and points to potential areas for further improvement in enhancing the overall pilgrim experience. In conclusion, the analytical outputs of this study have adeptly encapsulated the multifaceted nature of the Hajj experience, merging emotional, physical, and participatory aspects. This holistic method of data analysis establishes a new standard in the comprehension of religious pilgrimages and serves as an invaluable reference for future research aimed at investigating similar phenomena.

**6. Conclusive Remarks and Prospects for Future Research** In summation, this research makes a significant contribution to the field by shedding light on the emotional and physical dynamics of pilgrims during the Hajj. The study's exploration of the correlation between physical states and emotional well-being has deepened our comprehension of the intricate relationship between these facets. Looking ahead, there is an opportunity to expand upon this work through the application of more sophisticated statistical models and the consideration of external factors that may impact emotional states. Additionally, integrating diverse data sources could pave the way for a more holistic analysis. This study underlines the vital role of cutting-edge technologies and data analytics in decoding the human experience in the context of religious pilgrimages, offering a template for future research endeavors. This study's innovative use of interactive heatmaps, generated from extensive geographical data and visualized using Python's Folium library, represents a leap forward in data interaction and visualization. The production of these interactive HTML files has opened new avenues for engaging with the data, allowing users not just to view but to interact dynamically with the spatial information. By

navigating through these maps, users can discern patterns of high and low pilgrim density, thereby gaining a deeper understanding of the distribution and movement of participants across different Hajj activities. These interactive visualizations are invaluable tools, enabling the pinpointing of specific areas that might require additional focus or investigation. This approach has greatly enhanced our grasp of pilgrim mobility and engagement, contributing significantly to the comprehensive assessment of the pilgrimage experience. In essence, the advanced methodologies and analytical techniques employed in this study not only enrich our understanding of the Hajj pilgrimage but also set a precedent for future explorations into the complexities of emotional states, physical well-being, and activity engagement in such spiritually profound and large-scale events.

## References:

- [1] A. Rayan, M. Sisan, & O. Baker, "Stress, workplace violence, and burnout in nurses working in king abduallah medical city during al-hajj season", *Journal of Nursing Research*, vol. 27, no. 3, p. e26, 2019. <https://doi.org/10.1097/jnr.0000000000000291>
- [2] S. Benkouiten, J. Al-Tawfiq, Z. Memish, & A. Albarak, "Clinical respiratory infections and pneumonia during the hajj pilgrimage: a systematic review", *Travel Medicine and Infectious Disease*, vol. 28, p. 15-26, 2019. <https://doi.org/10.1016/j.tmaid.2018.12.002>
- [3] S. Shaikh, H. Ashraf, K. Shaikh, H. Iraqi, M. Mbaye, A. Kakeet al., "Diabetes care during hajj", *Diabetes Therapy*, vol. 11, no. 12, p. 2829-2844, 2020. <https://doi.org/10.1007/s13300-020-00944-5>
- [4] M. Aldossari, A. Aljoudi, & D. Celentano, "Health issues in the hajj pilgrimage: a literature review", *Eastern Mediterranean Health Journal*, vol. 25, no. 10, p. 744-753, 2019. <https://doi.org/10.26719/2019.25.10.744>
- [5] Y. Jing, H. Zhu, R. Bi, & M. Hou, "Using temporal and spatial scales to unravel the effects of climatic factors on vegetation variations in china", *Frontiers in Ecology and Evolution*, vol. 9, 2021. <https://doi.org/10.3389/fevo.2021.730673>
- [6] J. Dyck, R. Tate, J. Uhanova, & M. Torabi, "Social determinants and spatio-temporal variation of ischemic heart disease in manitoba", *BMC Public Health*, vol. 21, no. 1, 2021. <https://doi.org/10.1186/s12889-021-12369-1>
- [7] S. Bie, X. Hu, H. Zhang, K. Wang, & Z. Dou, "Influential factors and spatial-temporal distribution of tuberculosis in mainland china", *Scientific Reports*, vol. 11, no. 1, 2021. <https://doi.org/10.1038/s41598-021-85781-7>
- [8] B. Kim and C. Yong, "The effects of spirituality on visitor behavior: a cognitive-affective-conative model", *International Journal of Tourism Research*, vol. 23, no. 6, p. 1151-1162, 2021. <https://doi.org/10.1002/itr.2474>
- [9] J. Duarte, L. Sarmiento, & D. Rodríguez-Padilla, "Methodological proposal for the identification of tourist routes in a particular region through clustering techniques", *Heliyon*, vol. 7, no. 4, p. e06655, 2021. <https://doi.org/10.1016/j.heliyon.2021.e06655>
- [10] S. Khosyi'ah, B. Faizin, D. Maylawati, & M. Ramdhani, "Society education media about islamic law through web-based application", 2021. <https://doi.org/10.2991/assehr.k.210715.096>
- [11] L. Ht, "Prediction of covid 19 and its economic impact in africa", 2021. <https://doi.org/10.20944/preprints202104.0767.v1>
- [12] J. Liu, Z. Zha, W. Wu, K. Zheng, & Q. Sun, "Spatial-temporal correlation and topology learning for person re-identification in videos", 2021. <https://doi.org/10.48550/arxiv.2104.08241>
- [13] Z. Zheng, L. Shi, L. Sun, & J. Du, "Short-term traffic flow prediction based on sparse regression and spatio-temporal data fusion", *IEEE Access*, vol. 8, p. 142111-142119, 2020. <https://doi.org/10.1109/access.2020.3013010>
- [14] M. Khan, K. Ahmad, S. Shakeel, & M. Qasim, "Health knowledge and attitude practices in pakistani hajj pilgrims.", *The Professional Medical Journal*, vol. 27, no. 02, p. 359-364, 2020. <https://doi.org/10.29309/tpmj/2020.27.02.3988>
- [15] T. Araki and S. Akaho, "Spatially multi-scale dynamic factor modeling via sparse estimation", *International Journal of Mathematics for Industry*, vol. 11, no. 01, 2019. <https://doi.org/10.1142/s2661335219500059>
- [16] K. Takiyama, H. Yokoyama, N. Kaneko, & K. Nakazawa, "Detecting task-dependent modulation of spatiotemporal module via tensor decomposition: application to kinematics and emg data for walking and running at various speed", 2019. <https://doi.org/10.1101/700872>



## Detection of Covid-19 Using Efficient Ensemble Learning with Convolutional Neural Network

Ammar Arbaeen<sup>1\*</sup>, Yusuf Aleshinloye Abass<sup>2</sup>

1- Scientific Information and Services Department, The Custodian of The Two Holy Mosques Institute For Hajj And Umrah Research, Umm Al-Qura University, 2- Department Of Computer Science, Nile University of Nigeria.

\*Corresponding author: E-mail (afarbaeen@uqu.edu.sa)

### الكشف عن فيروس كوفيد-19 باستخدام مجموعة طرق التعلم الفعال مع الشبكة العصبية التلافيفية

عمار فؤاد اربعين<sup>1\*</sup>، يوسف عباس<sup>2</sup>

1- قسم المعلومات والخدمات العلمية، معهد خادم الحرمين الشريفين لبحوث الحج والعمرة، جامعة أم القرى، 2- قسم علوم الحاسب الآلي، جامعة النيل  
النيجيرية.

#### الملخص

تقام كل عام مئات الأحداث المزدحمة في جميع أنحاء العالم. وأغلب الفعاليات المزدحمة ذات أصل ديني، كالحج والعمرة تكون مشحونة بالحساسيات والعواطف. يعد تنظيم التجمعات المزدحمة، خاصة أثناء جائحة مثل كوفيد-19، صعوبة كبيرة. لقد أصاب فيروس كوفيد-19 229 دولة ومنطقة حول العالم ولا يزال يلحق الدمار بحياة الناس. يهدف هذا البحث إلى الاكتشاف المبكر للمصابين بفيروس كورونا حيث تعد مشكلة حاسمة للممارسين الطبيين والحكومات والمنظمات في أي منطقة جغرافية. إن مكافحة الانتشار السريع لفيروس كورونا أصبح مطلباً هاماً حيث من الضروري اكتشاف الأشخاص المصابين بسرعة وأقل تكلفة. إحدى الطرق الأكثر واقعية لتحقيق هذا الهدف هي من خلال التقييم الإشعاعي، حيث تعد الأشعة السينية للمصدر هي البديل الأسهل والأقل تكلفة. في هذا البحث تم اقتراح منهجية بتوظيف تقنية التعلم العميق كوسيلة من وسائل الذكاء الاصطناعي باستخدام الشبكات العصبية للصور الطبية. تقدم هذه الورقة طريقة لتطوير طرق الكشف عن كوفيد-19 التي تستلزم تطبيق تقنيات نقل التعلم على نموذجين عالي الأداء، وهما DenseNet121 وResnet50، باستخدام مجموعة بيانات كبيرة من CXRs تحتوي على 21,715 صورة لكوفيد-19. حققت DenseNet دقة في نتائج التدريب والاختبار بلغت 92.28% و94% على التوالي، مع حساسية ونوعية بلغت 94%. وحققت ResNet دقة في نتائج التدريب والاختبار بلغت 80.14% و80% على التوالي. تم بعد ذلك إخضاع النماذج الأفضل أداءً لمنهج المجموعة المتوسطة المرجحة، مما أدى إلى دقة بلغت 95.1%، فضلاً عن حساسية ونوعية بنسبة 94%. تم تطوير منصة تطبيق ويب لمهمة الكشف عن كوفيد-19 والتي ستمكن الممارسين الطبيين من إجراء الكشف عن كوفيد-19 عن طريق تحميل صور CXRs إلى تطبيق الويب.

#### Abstract

Every year, hundreds of crowded events are held all over the world. The majority of the crowded events are religious in origin, such as Hajj and Umrah, and are fraught with sensitivities and emotions. Organizing crowded gatherings, particularly during a pandemic like COVID-19, is a significant difficulty. COVID-19 has infected 229 countries and territories worldwide and is still wreaking havoc on people's lives. The early detection of COVID-19 patients is a crucial

problem for medical practitioners, governments, organizations in any geographical region. To tackle this condition and to combat the fatal virus's rapid spread it is vital to detect afflicted people quickly and cheaply. One of the most realistic ways to achieve this aim is through radiological evaluation, with a chest X-Ray being the most easily accessible and least expensive alternative. In this paper, we have proposed a Deep Convolutional Neural Networks for medical images. Using this methodology, this paper presents a way for developing a COVID-19 detection method that entails applying transfer learning techniques to two highly performing models, namely DenseNet121 and Resnet50, using a large dataset of CXRs containing 21,715 COVID-19 images. DenseNet achieved training and testing accuracy of 92.28% and 94%, respectively, with sensitivity and specificity of 94%. The ResNet achieved training and testing accuracy of 80.14% and 80%, respectively. The best-performing models were then subjected to a weighted average ensemble approach, which resulted in an accuracy of 95.1%, as well as sensitivity and specificity of 94%. A web application platform was developed for the task of COVID-19 detection which will enable medical practitioners to perform the detection of COVID-19 by uploading the CXRs images to the on the web application.

**Keywords:** Detection, Deep Learning, X-Rays, Transfer Learning.

## 1. Introduction

In general, planning a large-scale event requires sophisticated management techniques. However, planning such an event during a crisis or epidemic that calls for social distance and other limitations would require a new set of abilities and guidelines, which may be difficult to put into practice. The COVID-19 pandemic [1] which began in China in 2019, is affecting us. More than 200 million individuals have contracted the virus so far, and more than 4 million have died as a result. The effectiveness of international attempts to stop the virus's spread has been uneven thus far. The majority of the nations have seen several viral waves. Sadly, COVID-19 has evolved into several strains since its inception. COVID-19 has evolved from the Omicron variant to the Delta variant and this is due to the significant change in the genetic constituent of the first SAR-COV-2 gene.

Although several vaccinations have been licensed by the World Health Organization (WHO) for use in emergencies, their efficacy remains in doubt. There are no known effective COVID-19 therapy. Nonetheless, there are a few widely accepted and efficacious strategies to keep the COVID-19 virus under control. Social separation, exposure limitation, mask-wearing in public, frequent hand washing, and sensitization are a few of them.

In the case of a pandemic, crowd management companies are required to adhere to and execute well-recognized safety protocols and guidelines. In fact, a lot of activities are planned in line with the pandemic's needs during the coronavirus outbreak. Sadly, a lot of extremely packed event that deviates from the usual COVID-19 protocols has also been observed. Certain incidents have shown to be quite effective in dispersing the coronavirus over several areas and towns. However, certain events have gone forward in the hopes of obtaining an edge in politics. Numerous events could have been canceled completely or scheduled with requirements. These events' success or failure must be ascribed to the nation's management of the coronavirus in a crowded event [2].

The Hajj and Umrah events that were organized during the pandemic followed all the rules, and both events serve as excellent examples of how well-managed packed gatherings can be under COVID-19. The Hajj is a yearly pilgrimage to Makkah (Mecca), whereas the Umrah is a continuous pilgrimage that occurs in Makkah on all of the days and months of the year. Approximately ten million people come from all over the world to take part in these pilgrimages throughout the



regular seasons. But things are very different during the epidemic. Both Hajj and Umrah pilgrimage exercise was different during the COVID-19 year. All pilgrims are expected to adhere to strict guidelines from the organizers of the events [3]. In this article, we examine the detective capabilities of the Convolutional Neural Network (CNN). To assess the detective ability of the model, we use several detective criteria.

## 2. Related Work

Medical diagnosis has made significant use of computer vision. It is helpful in medical specialties like dermatology that call for visual examinations. To determine whether a skin irregularity is an early warning sign of skin cancer, computer vision is utilised as a diagnostic tool. Additionally, it is employed to identify problems with the body, particularly with the joints, blood vessels, tissues, etc. It helps to avoid blindness in ophthalmology by diagnosing conditions like diabetic retinopathy. Along with medicines, it has also shown great success in surgeries as well as therapies. Medical imaging data from CT, MRI, PET, ultrasound, and chest X-ray (CXR) scans are among the many forms of imaging data that are used in computer vision systems. Research shows that to enhance the diagnosis of viral infection in the lungs, medical imaging is beneficial. Deep learning-based methods for diagnosing pneumonia [4], other thoracic disease classes [5], skin cancer [6], hemorrhage categorization [7], and other conditions from medical images have been created in several projects. Even though their design is very basic, several of these research have shown encouraging results [4]. A convolutional neural network (CNN) model has been utilized in a study by Singh et al. [8] detect COVID-19 patients using CT scan images. A CT scan can be used in a number of further research studies to identify the presence of the COVID-19 virus in human lungs [9]. With the use of CT scan images, a multi-task, self-supervised AI model has been created by Yan et al. [9] the model recorded 89% accurate diagnosis of the COVID-19 virus in human lungs. Shan et al. perform automatic lung segmentation and quantification [8]. A completely automated system to identify and distinguish coronavirus-affected lungs from other lung illnesses is described by Li et al. [10] using chest CT scan images. Notwithstanding, Ng et al. [11] and Huang et al. [12] have determined that CXR images outperform all other methods in the identification of COVID-19 due to their encouraging outcomes, accessibility of CXR equipment, and inexpensive cost. Researchers have worked on the subject of COVID-19 patient identification using CXR images in a number of different studies [13]. In one such study, Makris et al. [14] classified normal, pneumonia, and COVID-19 patients using CXR images by utilising transfer learning with the Inception-v3 network. In a different study, Mangal et al [15] separated COVID-19 patients, bacterial and viral pneumonia patients, and normal people using the DenseNet with ChexNet design. The majority of researchers in this field are confronted with the difficulty of limited imaging data availability for Covid-19 positive patients. Waheed et al.'s study [16] developed COVIDGAN to create fake data, which will aid in better COVID-19 detection.

## 3. Proposed Method

In this study, the transfer learning approach and the weighted average ensemble technique are used in developing a CNN model for the detection of COVID-19 from chest X-Ray images. The first task was to apply the transfer learning technique on 4 pre-trained CNN models namely DenseNet, ResNet50, VGG-16, and Inception. These models are pre-trained on a large dataset and have learned to extract useful features from the images. After applying the transfer learning technique, the performances of all the models are compared to identify the best-performing model. A weighted average ensemble was applied to the best-performing models to see if the performance increased. This newly proposed ensemble method combines the predictions of the individual models using a weighted average technique. The models were developed and evaluated, a web application was created to carry out detection tasks. This web application is accessible to healthcare

professionals who can upload chest X-ray images for detection. Lastly, a mobile application that can receive the results of the test was developed as well. The mobile application provides a user-friendly interface for patients to access their test results on their smartphones.

#### 4. Pre-Trained Models

##### A. DenseNet.

In DenseNet, by directly linking all network levels with corresponding feature-map sizes, it is intended to maximize information flow between layers. The design employs dense connection patterns, where each layer receives new inputs from all levels that came before it and transmits its own feature maps to all layers that came after it without first combining them by summation. Instead, concatenation is used to merge the features. L-layer networks as a result have  $L(L+1)/2$  connections, which is greater than conventional systems. The main benefit of Dense Convolution Network, also known as DenseNet, is that it uses far fewer parameters than comparable varieties of classic CNN, as illustrated in Figure 1.0.

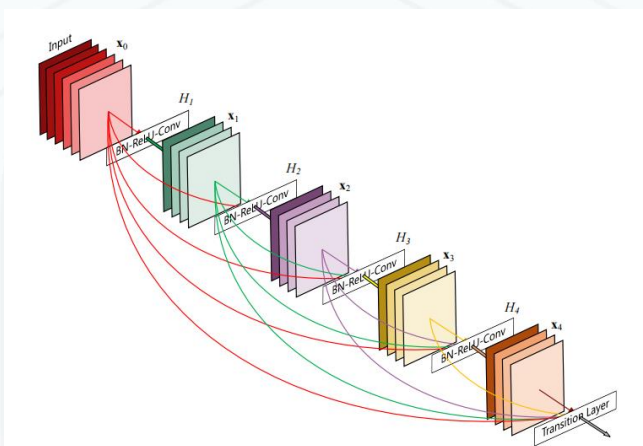


Figure 6 Shows A5-layer dense block with a growth rate of  $k=4$

The DenseNet, a single image  $x_0$  is sent via a convolutional neural network. The network is made up of  $L$  layers, each of which carries out the non-linear transformation  $H_L(\cdot)$ , where the layer index is used.  $H_L(\cdot)$  can be a composite function of several processes, including Convolution (Conv), Pooling [17], Rectified linear units (ReLU) [18], and Batch Normalisation (BN) [19].

##### B. ResNet

The ResNet50 is a modern convolutional neural network that incorporates "residual blocks" to tackle the issue of vanishing or exploding gradients. The architecture of a residual network is made up of multiple residual blocks, where each block contains shortcut connections that skip one or more layers. To achieve this, ResNet50 employs pre-activation weight layers [20].

##### C. VGG-16

Convolutional neural networks like VGG were created by Google's DeepMind and the Visual Geometry Group Laboratory. The VGG model creates a deeper convolution neural network structure by utilising a relatively tiny ( $3 \times 3$ ) convolution kernel [21]. A convolution layer (five layers), a complete connection layer (three tiers), and a softmax output layer make up the fundamental mechanism. Max pooling is the amount of time gap between layers. Instead of using

several huge convolution kernel layers, VGG employs few relatively tiny ( $3 \times 3$ ) convolution kernel layers. As a result, the parameters are reduced and the network's capacity is increased [22].

#### D. INCEPTION

A neural network called the inception block consists of a single  $1 \times 1$  convolution,  $3 \times 3$  convolutions followed by  $1 \times 1$  convolutions,  $5 \times 5$  convolutions followed by  $1 \times 1$  convolutions, a  $3 \times 3$  max pool layer followed by  $1 \times 1$  convolutions, and so on. The theory is that some of the convolutions and pooling in a block will be effective enough to extract some useful information from the photos if we utilise them all. The  $5 \times 5$  layer has a padding of 2, and the  $3 \times 3$  convolutions have a padding of 1, to ensure that the picture dimensions are preserved and the input and output images are of equal size. Finally, they are all piled on top of one another [23].

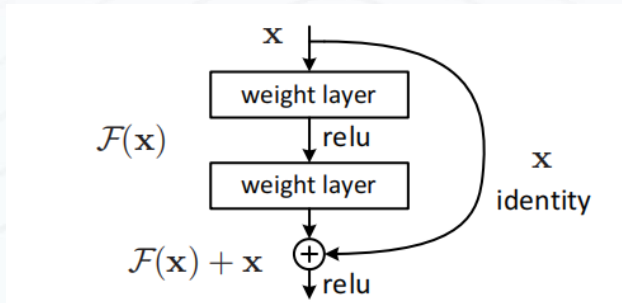


Figure 7 The structure of ResNet with residual building block [21].

### 5. Transfer Learning

The approach of utilizing pre-trained models on a new problem is known as transfer learning. This involves adapting the base model by retraining its layers with new data from the problem domain. A pre-existing network refers to a network that was previously trained on a large dataset, usually for image classification, and its architecture and weights were saved. If the original dataset is extensive and inclusive enough, the pre-existing network can learn enough features to be a useful general model for the visual world. Consequently, these features can be advantageous for various computer vision tasks, even if the new tasks have completely different categories from those of the original task.

The first step in transfer learning is to modify the base model's architecture to suit the specific regression or classification task, typically achieved by replacing the output layer with a new layer that matches the desired number of outputs or classes. Afterwards, the pre-trained weights are loaded, and the model can be fine-tuned in three different modes:

- i. Feature extraction, where only the new output layer is trained while other layers remain unchanged;
- ii. Gradual unfreezing, where some of the last layers of the base model are retrained while other layers remain frozen;
- iii. Fine-Tuning, which would be the method used, where both the base network and the new output layer are retrained.

The primary objective of the learning process is to minimize the objective function, which consists of the loss function and the regularization term that controls the weight gradient's size.

### 6. Ensemble Model Technique

The weighted average ensembling method is a technique used to combine the outputs of multiple models in order to improve the overall performance of the prediction. The basic idea of the weighted average ensemble method is to assign a weight to each model in the ensemble and compute the weighted average of their predictions.

The weights can be assigned in different ways, such as based on the performance of the individual models on a validation set or by giving equal weights to all models, or by using an algorithm such as Grid Search to find the optimal weights for each model, in order to get the highest accuracy, however the most common way is when the weights assigned to each individual model are determined based on their performance, with the model that performs better being assigned a higher weight. The advantage of the weighted average ensemble method is that it can improve the performance of the individual models by leveraging their strengths and mitigating their weaknesses.

## 7. Materials and Methods

### A. Dataset

In this work, a single dataset called the COVID-QU-Ex dataset was used which represent the study population for this research [24]. The COVID-QU-Ex dataset, compiled by researchers from Qatar University, and as at the time it was accessed, it is a collection of 33,920 chest X-ray images. It includes 11,956 COVID-19 cases, 11,263 cases of non-COVID viral or bacterial pneumonia, and 10,701 normal cases. The dataset also provides ground-truth lung segmentation masks, which the largest lung mask dataset is ever created [22].

The COVID-QU-Ex dataset is unique as it is the first to use both lung and infection segmentation to detect, localize, and quantify COVID-19 infection from X-ray images. This can help medical professionals diagnose the severity of COVID-19 pneumonia and monitor the disease's progression.

The X-ray images in the COVID-QU-Ex dataset were publicly available online and obtained from various repositories and studies, including QaTar-COVID19 Database the Institute for Diagnostic and Interventional Radiology, Hannover Medical School in Hannover, Germany. SIRM - Società Italiana di Radiologia Medica e Interventistica Medical Imaging Databank of the Valencia region (BIMCV), National Institutes of Health Clinical Center, Guangzhou Women and Children's Medical Center, Guangzhou [25] and others.



Figure 8 CXR Images of COVID-19 positive cases



Figure 9 CXR images of Normal cases



Figure 10 CXR Images of None COVID-19 cases

### B. Data Preprocessing

Pre-processing operations are performed on the image data via the pre-processing functions provided by the Keras library for each pre-trained model. Using the pre-process function for the DenseNet, ResNet50 and VGG-19 models, the input images undergo a color space conversion from RGB to BGR. The pixel values of each color channel are then centered around zero by subtracting the mean RGB values of the ImageNet dataset. However, the pixel values are not scaled after centering. This process helps the model to focus on the relative differences between the pixel values rather than the absolute pixel values. While for the Inception model, the input pixel values undergo a sample-wise scaling transformation that maps the original range of pixel values to the range of -1 to 1. This scaling is performed to ensure that the pixel values have a uniform distribution and to improve the stability of the model during training. The images were resized to a specific size of 224 \* 224, they were then shuffled in the training set in order for the model to see images in a random order during training, increasing its ability to learn features more effectively. And finally, pre-processed image batches were generated for the train, test and validation datasets.

### 8. Experimental Result

The implemented model is trained for 10 epochs using the ImageDataGenerator's `flow_from_directory()` function. During training, the ModelCheckpoint callback is used to save the best-performing model as .h5 files based on validation accuracy. After training the model was seen to have an accuracy and validation accuracy of 92.28% and 93.23% respectively. The progress of loss and accuracy (for both training and validation) across the epochs for the Densenet are illustrated in Figure 6, as well as a table detailing the classification report regarding its performance on the test set.

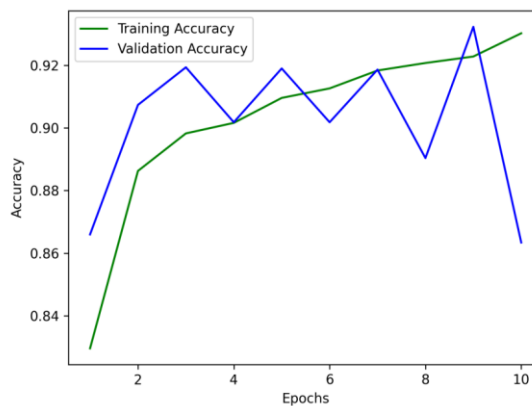


Figure 11 Training and validation accuracies of the model

Table 2 Showing the results for the detection using DenseNet

	PRECISION	RECALL	F1-SCORE
0	0.97	0.98	0.97
1	0.90	0.95	0.93
2	0.95	0.89	0.92
ACCURACY			0.94
MACRO AVG	0.94	0.94	0.94
WEIGHTED AVG	0.94	0.94	0.94

The next model, being the ResNet50, was trained with the same hyperparameters as the DenseNet, and was seen to achieve an accuracy and validation accuracy of 74.53% and 80.14% respectively. The following is the model's classification report.

Table 3 Showing the result for the detection using ResNet

	PRECISION	RECALL	F1-SCORE
0	0.87	0.95	0.91
1	0.70	0.85	0.77
2	0.87	0.58	0.69
ACCURACY			0.80
MACRO AVG	0.81	0.79	0.81
WEIGHTED AVG	0.81	0.80	0.81

Finally, with a weighted average ensemble of both models, the optimal weights of 0.99256378, 0.00743622 for DenseNet and ResNet respectively, during the evaluation of the new ensemble model, an accuracy of 95.3% was recorded. The following is the classification report for this model.

Table 4 Showing the result for the detection using Weighted Average of both models

	PRECISION	RECALL	F1-SCORE
0	0.97	0.98	0.98
1	0.90	0.96	0.93
2	0.95	0.89	0.92
ACCURACY			0.95
MACRO AVG	0.94	0.94	0.94
WEIGHTED AVG	0.94	0.94	0.94

From the table above, we can see that while being very similar to the best performing individual model, DenseNet121, we see changes in the precision and F1-Score values for different classes, and an overall slight increase in accuracy to 95% for the ensemble method.

## 9. Discussion

This section presents and discusses the outcome of the experiments we conducted. The weight that were given for each of the aforementioned experimental metric varies across domains where they are applicable. The implemented model were all tested by varying the parameters such as number of epoch and number of layers. The implemented model were evaluated using different classification metrics include accuracy, precision, recall and the F1-score. The F1-score is the sum of the recall and accuracy values which was used for this assessments. The classification metrics were all calculated based on the confusion metric which obtain the true positive, true negative, false positive and false negative. The first model that was trained was the DenseNet121, the fully connected layer is modified to have an output of 3 classes using

a sigmoid activation function. The Adam optimizer is used with a learning rate of 0.001 and the loss function used is categorical cross-entropy, the training dataset is split into batches of 32 and preprocessed using the DenseNet preprocessor, the validation and test datasets are also preprocessed using the same preprocessor. The assessment of DenseNet121 model has achieved training and testing accuracy of 92.28% and 94%, respectively, with sensitivity and specificity of 94%. Moreover, the assessment of ResNet model has achieved training and testing accuracy of 80.14% and 80%, respectively. The best-performing models were then subjected to a weighted average ensemble approach, which resulted in an accuracy of 95.1%, as well as sensitivity and specificity of 94%. Despite the performance increment that were detected by the implemented model it is very much similar to the individual performance of the DenseNet121 model.

## 10. Conclusion

In conclusion, we have developed a CNN model for the detection of COVID-19 using chest X-ray images. Our approach involved applying transfer learning on pre-trained CNN models, including Densenet and Resnet, and selecting the best performing models. We then applied a weighted average ensemble method to further improve the model's performance. The ensemble method resulted in an accuracy of 95.1% with sensitivity, specificity, and F1-score being 94%. Moreover, we developed a web app that enables users to carry out detection tasks and a mobile app to receive the results of the test. Our approach provides a reliable and efficient tool for the detection of COVID-19, which can be used by authorities that are in charge of hajj and Umrah exercise. Overall, our results demonstrate the effectiveness of CNN models in medical image classification tasks and their potential for improving healthcare outcomes.

## References

- [1] M. Yamin, "Counting the cost of COVID-19," *International journal of information technology*, vol. 12, p. 311–317, 2020.
- [2] H. Bardesi, A. Al-Mashaikhi, A. Basahel and M. Yamin, "COVID-19 compliant and cost effective teaching model for King Abdulaziz University," *International Journal of Information Technology*, vol. 13, p. 1343–1356, 2021.
- [3] M. Yamin, "Managing crowds with technology: cases of Hajj and Kumbh Mela," *International journal of information technology*, vol. 11, p. 229–237, 2019.
- [4] V. Chouhan, S. K. Singh, A. Khamparia, D. Gupta, P. Tiwari, C. Moreira, R. Damaševičius and V. H. C. De Albuquerque, "A novel transfer learning based approach for pneumonia detection in chest X-ray images," *Applied Sciences*, vol. 10, p. 559, 2020.
- [5] P. Rajpurkar, J. Irvin, K. Zhu, B. Yang, H. Mehta, T. Duan, D. Ding, A. Bagul, C. Langlotz, K. Shpanskaya and others, "Chexnet: Radiologist-level pneumonia detection on chest x-rays with deep learning," *arXiv preprint arXiv:1711.05225*, 2017.
- [6] A. Esteva, B. Kuprel, R. A. Novoa, J. Ko, S. M. Swetter, H. M. Blau and S. Thrun, "Dermatologist-level classification of skin cancer with deep neural networks," *nature*, vol. 542, p. 115–118, 2017.
- [7] M. Grewal, M. M. Srivastava, P. Kumar and S. Varadarajan, "Radnet: Radiologist level accuracy using deep learning for hemorrhage detection in ct scans," in *2018 IEEE 15th International Symposium on Biomedical Imaging (ISBI 2018)*, 2018.
- [8] D. Singh, V. Kumar, Vaishali and M. Kaur, "Classification of COVID-19 patients from chest CT images using multi-objective differential evolution–based convolutional neural networks," *European Journal of Clinical Microbiology & Infectious Diseases*, vol. 39, p. 1379–1389, 2020.
- [9] Q. Yan, B. Wang, D. Gong, C. Luo, W. Zhao, J. Shen, Q. Shi, S. Jin, L. Zhang and Z. You, "COVID-19 chest CT image segmentation—a deep convolutional neural network solution," *arXiv preprint arXiv:2004.10987*, 2020.
- [10] L. Li, L. Qin, Z. Xu, Y. Yin, X. Wang, B. Kong, J. Bai, Y. Lu, Z. Fang, Q. Song and others, "Artificial intelligence distinguishes COVID-19 from community acquired pneumonia on chest CT," *Radiology*, 2020.

- [11] E. M. Chamorro, A. D. Tascón, L. I. Sanz, S. O. Vélez and S. B. Nacenta, "Radiologic diagnosis of patients with COVID-19," *Radiología (English Edition)*, vol. 63, p. 56–73, 2021 .
- [12] C. Huang, Y. Wang, X. Li, L. Ren, J. Zhao, Y. Hu, L. Zhang, G. Fan, J. Xu, X. Gu and others, "Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China," *The lancet*, vol. 395, p. 497–506, 2020 .
- [13] I. D. Apostolopoulos and T. A. Mpesiana, "Covid-19: automatic detection from x-ray images utilizing transfer learning with convolutional neural networks," *Physical and engineering sciences in medicine*, vol. 43, p. 635–640, 2020 .
- [14] A. Makris, I. Kontopoulos and K. Tserpes, "COVID-19 detection from chest X-Ray images using Deep Learning and Convolutional Neural Networks," in *11th hellenic conference on artificial intelligence*, 2020 .
- [15] A. Mangal, S. Kalia, H. Rajgopal, K. Rangarajan, V. Namboodiri, S. Banerjee and C. Arora, "CovidAID: COVID-19 detection using chest X-ray," *arXiv preprint arXiv:2004.09803*, 2020 .
- [16] A. Waheed, M. Goyal, D. Gupta, A. Khanna, F. Al-Turjman and P. R. Pinheiro, "Covidgan: data augmentation using auxiliary classifier gan for improved covid-19 detection," *IEEE Access*, vol. 8, p. 91916–91923, 2020 .
- [17] I. H. Sarker, "Machine learning: Algorithms, real-world applications and research directions," *SN computer science*, vol. 2, p. 160, 2021 .
- [18] J. Schmidt, M. R. G. Marques, S. Boti and M. A. L. Marques, "Recent advances and applications of machine learning in solid-state materials science," *npj Computational Materials*, vol. 5, p. 83, 2019 .
- [19] M.-H. Guo, T.-X. Xu, J.-J. Liu, Z.-N. Liu, P.-T. Jiang, T.-J. Mu, S.-H. Zhang, R. R. Martin, M.-M. Cheng and S.-M. Hu, "Attention mechanisms in computer vision: A survey," *Computational visual media*, vol. 8, p. 331–368, 2022 .
- [20] R. Gomes, C. Kamrowski, J. Langlois, P. Rozario, I. Dircks, K. Grottodden, M. Martinez, W. Z. Tee, K. Sargeant, C. LaFleur and others, "A comprehensive review of machine learning used to combat COVID-19," *Diagnostics*, vol. 12, p. 1853, 2022 .
- [21] G. Pang, C. Shen, L. Cao and A. V. D. Hengel, "Deep learning for anomaly detection: A review," *ACM computing surveys (CSUR)*, vol. 54, p. 1–38, 2021 .
- [22] B. M. Tabi Fouda, D. Han, B. An, X. Lu and Q. Tian, "Events detection and recognition by the fiber vibration system based on power spectrum estimation," *Advances in Mechanical Engineering*, vol. 10, p. 1687814018808679, 2018 .
- [23] C. Si, W. Yu, P. Zhou, Y. Zhou, X. Wang and S. Yan, "Inception transformer," *Advances in Neural Information Processing Systems*, vol. 35, p. 23495–23509, 2022 .
- [24] D. Kuzinkovas and S. Clement, "The detection of covid-19 in chest x-rays using ensemble cnn techniques," *Information*, vol. 14, p. 370, 2023 .
- [25] R. Ghanam, E. L. Boone and A.-S. G. Abdel-Salam, "Seird model for Qatar covid-19 outbreak: a case study," *arXiv preprint arXiv:2005.12777*, 2020 .



الملتقى العلمي الثالث والعشرون  
لأبحاث الحج والعمرة والأبارة  
التميز الصحي في خدمة ضيوف الرحمن



جامعة أم القرى  
معهد خادم الحرمين الشريفين  
للأبحاث الحج والعمرة

## Theme of Environmental Sustainability and the Health of the Pilgrims



## From Pilgrimage to Sustainable Practice: Leveraging Artificial Intelligence for the Future of Hajj

Alanoud A. Aljuaid

Computer Science, Cyber Security, Umm Al-Qura University

\*Corresponding author: E-mail (aajeeid@uqu.edu.sa)

### من الحج إلى الممارسة المستدامة: الاستفادة من الذكاء الاصطناعي لمستقبل الحج

العنود عواض الجعيد

علوم الحاسب، أمن سيبراني، جامعة أم القرى

#### المخلص

سنوياً، يجذب الحج، وهو أحد العناصر الأساسية في أركان الإسلام الخمسة، الملايين من المسلمين إلى مكة في عرض مثير للإعجاب للالتزام الديني. يمثل هذا التجمع الضخم، على الرغم من الجهود الحثيثة التي تبذلها المملكة العربية السعودية لتحسين الخدمات التي تدعمه، معضلات معقدة تتعلق بالخدمات اللوجستية والحفاظ على البيئة وضغط البنية التحتية. ومع تحول التركيز العالمي بشكل متزايد نحو المنهجيات والممارسات المستدامة، يصبح من الأهمية بمكان فهم التأثير على الاستدامة الناتج عن مثل هذه الأحداث الكبرى. مع الضجة الأخيرة للذكاء الاصطناعي (AI)، هناك اهتمام متزايد باستخدام قيمته عبر مختلف القطاعات في جميع أنحاء العالم. ويوضح هذا البحث بشكل بناء كيف يمكن للذكاء الاصطناعي أن يُحدث ثورة في الأساليب الرامية إلى معالجة قضايا الاستدامة المتنوعة المرتبطة بالحج. يستخدم هذا البحث بيانات ثانوية من الأدبيات لتقديم نتائج قوية ومدعومة بالأدلة لهذا البحث. ويشمل ذلك الدراسات السابقة حول الآثار البيئية للحج؛ المبادرات الحالية التي تهدف إلى الاستدامة؛ بالإضافة إلى التطبيقات المؤكدة أو المحتملة للذكاء الاصطناعي ضمن سيناريوهات قابلة للمقارنة. إن نقطة الذروة في هذا البحث هي وجود هيكل قوي يقترح الاستخدام الاستراتيجي للذكاء الاصطناعي، والذي يمكن أن يساعد في ممارسات الاستدامة المتكاملة المرتبطة برحلات الحج. وتشير نتائج البحث إلى استراتيجيات مدعومة بالذكاء الاصطناعي تتعلق بإدارة التخلص من النفايات، وتحسين وسائل النقل، وتدابير السيطرة على الحشود، وحتى إدارة الخدمات اللوجستية. يشير الإطار الذي تم تطويره من هذا البحث إلى ضرورة النظر في استخدام الذكاء الاصطناعي في الأحداث الكبيرة التي تحدث في جميع أنحاء المملكة العربية السعودية لجذب المزيد من الاهتمام نحو أهمية البيانات. ومن خلال التعديلات ذات الصلة، يمكن للإطار المقترح أن يمهّد الطريق للمضي قدماً بما يتوافق مع الرؤية السعودية 2030 وبعدها بزيادة الاستدامة. ويتناول العمل المستقبلي تقييم واختبار الإطار المقترح لقياس ممارسات الاستدامة في الحج والمناسبات الوطنية في المملكة العربية السعودية.

الكلمات الدالة: الذكاء الاصطناعي، الاستدامة، الممارسات، الحج.

#### Abstract

Annually, the Hajj pilgrimage, a cardinal component of Islam's Five Pillars, attracts millions of Muslims to Mecca in an impressive exhibition of religious commitment. This massive assembly, despite the relentless efforts by the Kingdom of Saudi Arabia to improve the services that support it, presents intricate dilemmas about logistics, environmental

preservation, and infrastructural pressure. As global focus shifts increasingly towards sustainable methodologies and practices, it becomes crucial to comprehend the impact on sustainability generated by such grand-scale events. With the recent hype surrounding artificial intelligence (AI), there is a growing interest in utilizing its value across different sectors worldwide. This research constructively lays out how AI could potentially revolutionize approaches to addressing diverse sustainability issues linked to the Hajj. This research uses secondary data from the literature to provide robust and evidence-supported outcomes. This includes prior studies on Hajj's environmental consequences; existing initiatives aimed at sustainability; as well as proven or potential applications for AI within comparable scenarios.

The culmination point of this research is a robust structure suggesting strategic utilization of AI, which can help integrate sustainability practices associated with Hajj pilgrimages. Findings from the research suggest strategies powered by AI relating to waste disposal management, transportation optimization, crowd control measures, and even logistics management. The framework developed from this research suggests the need to look into utilizing AI in large events that occur across the Kingdom of Saudi Arabia, drawing more attention to the significance of data. With relevant adaptations, the suggested framework can pave the way forward feeding into Saudi Vision 2030 and promising increased sustainability. Future work investigates evaluating and testing the framework proposed to gauge sustainability practices within Hajj and national events in Saudi Arabia.

**Keywords:** Artificial Intelligence, Sustainability, Hajj, SDG

## 1. Introduction

Annually, the Hajj pilgrimage stands as a towering testament to religious devotion as millions of Muslims converge on Mecca to fulfill one of Islam's Five Pillars. This remarkable event is not just a spiritual journey but also a complex logistical and environmental endeavor (Quaium et al., 2023). The Kingdom of Saudi Arabia, in its commitment to facilitating this sacred gathering, faces the complex task of managing the immense influx of pilgrims (Felemban et al., 2021). This massive assembly, while a symbol of faith and unity, invariably brings intricate challenges related to logistics, environmental preservation, and infrastructural strain (Preko et al., 2022; Abalkhail and Al Amri, 2022). In the contemporary era, where sustainability has become a global priority, the Hajj presents a unique case study. The environmental footprint of such a large-scale event is substantial, encompassing aspects like waste management, water and energy usage, transportation logistics, and accommodation infrastructure (Al-Shaery et al., 2021). These elements, if not managed with foresight and responsibility, can have lasting impacts on the local environment and resources. Understanding and mitigating these impacts is crucial, not just for the preservation of Mecca's sacred sites, but also in aligning with broader environmental goals and global sustainability standards (Al-Habaibeh et al., 2020).

The recent surge in interest and advancements in artificial intelligence (AI) offers a promising avenue for tackling the multifaceted challenges of the Hajj pilgrimage. Recognized globally for its potential to revolutionize diverse sectors, AI's role in managing large-scale events like the Hajj is becoming increasingly pertinent. This research is poised to delve deep into the myriad ways AI can be harnessed to enhance sustainability practices during this massive gathering. By leveraging AI's capabilities in data analysis, predictive modeling, and automated decision-making, there is a significant opportunity to improve the efficiency and environmental footprint of the Hajj, transforming it into a model for sustainable large-scale event management.

The exploration of AI in the context of the Hajj is not just about the adoption of technology; it's about understanding and integrating it to address specific challenges of the pilgrimage. One key area is crowd management (e.g. Yasmin et al.,

2021; Zhou et al., 2021) using AI to analyze movement patterns and predict high-density areas, thereby enhancing safety and reducing the risk of overcrowding. Another crucial aspect is resource allocation. AI-driven systems can optimize the distribution and use of water, food, and energy, ensuring sustainable consumption and minimizing waste. Moreover, transportation during Hajj, a critical component of pilgrim management, can benefit immensely from AI. Intelligent transport systems, powered by AI algorithms, can optimize routes, reduce traffic congestion, and contribute to lower emissions. This aspect of AI application is not only about efficiency but also about reducing the environmental impact of the pilgrimage. Furthermore, AI can play a significant role in environmental monitoring.

By analyzing data from various sources, AI can help in tracking and managing the ecological footprint of the event, from air quality to waste disposal. This kind of environmental vigilance is essential in preserving the sanctity of Mecca and its surroundings, ensuring that the pilgrimage remains sustainable for future generations. This research, therefore, seeks to explore these various dimensions of AI application in the context of the Hajj. It aims to lay out a roadmap for the strategic utilization of AI, aligning with both the spiritual significance of the pilgrimage and the global imperative for sustainability.

## 2. Methodology

As discussed above, the goal of this paper is to lay out a roadmap for the strategic utilization of AI, aligning its potential contributions to sustainability. This paper draws upon research that made use of systematic literature review (SLR) as an approach to assess existing research on AI applications within Hajj and research published on sustainability within Hajj pilgrimage. SCOPUS also allows one to look for document titles, abstracts, and keywords with relevance to particular areas of research from database of over than 41,000 research publications (Harzing and Alakangas, 2016). SLR is considered as one of the robust processes that aims toward minimizing bias through transparent and meticulous literature search (Thome et al., 2016). For the SLR conducted in this paper, SCOPUS database was used to gather relevant peer-reviewed journals and conference proceedings.

In this research, two research questions (RQ) were formulated based on the screened literature on the impact of Artificial intelligence on sustainability for Hajj:

RQ 1: What is the impact of artificial intelligence (AI) on Hajj pilgrimage?

The objective of this research question was to identify what AI has contributed to Hajj pilgrimage, what aspects it tackled.

RQ2: What are the sustainability considerations within Hajj?

The objective of this research question was to highlight sustainability considerations within published research related to sustainability within Hajj.

For the SLR review, no restricted timeframe was integrated due to the uniqueness of the explored research. To conduct an informative search, SCOPUS search tool was used to look for document titles, abstracts, and keywords that relate to the selected areas of Artificial Intelligence, Sustainability, and Hajj. To encompass a wider range of results, the below:

- (TITLE-ABS-KEY ("artificial intelligence") AND TITLE-ABS-KEY (hajj) = 19 results
- (TITLE-ABS-KEY (sustainability) AND TITLE-ABS-KEY (hajj) = 12 results

The filtering process (see Figure 1) of the identified papers supported minimizing non-direct studies to the research questions. For RQ 1, the papers were analyzed chronologically (from latest to oldest) on areas focused on within Hajj by AI. As for RQ 2, the papers were analyzed concerning relevant sustainability development goals (SDGs), as this provides a more structured and standardized approach to the contributions of the research.

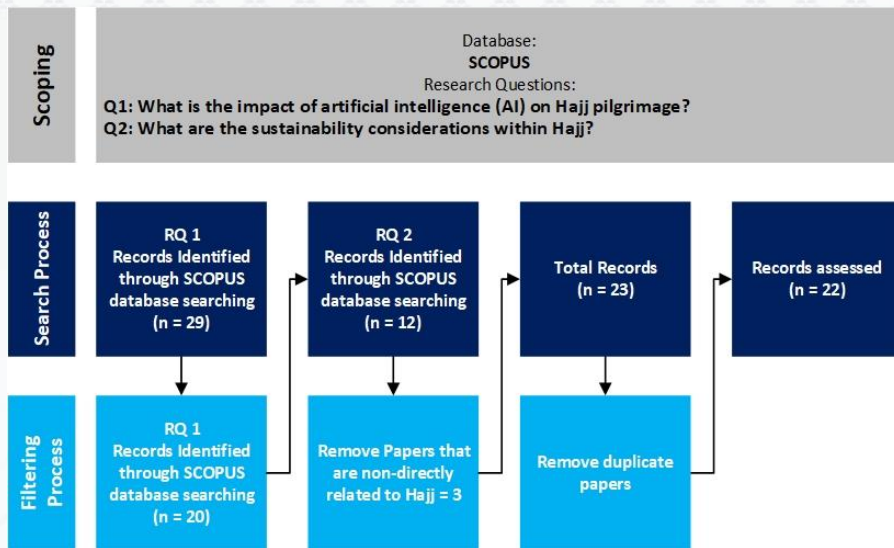


Figure 1: Literature Review selection process (author, 2023)

Table 1: Published literature on AI's impact on Hajj

Year	Authors	Impact of AI for Hajj
2023	Albahar et al.	Customer Satisfaction
2023	Fallatah and Imam	Land Surface Temperature Health and Well-being
2023	Luo et al.	Crowd Management
2023	Algamdi and Alghamdi	Vehicle Detection Crowd Management
2023	Alhameed and Hossain	Health and Well-being Crowd Management
2023	Al-Ghamdi et al.	Health and Well-being
2023	Yamin et al.	Crowd Management
2022	Shambour and Gutub	Health and Well-being Crowd Management Logistics Management
2022	Al-Shaery et al.	Health and Well-being Crowd Management
2022	Binsawad and Albahar	Crowd Management
2021	Elsheikh et al.	Health and Well-being
2021	Alhazmi et al.	Crowd Management
2020	Binhotan and Altameem	Health and Well-being
2019	Utama et al.	Crowd Management
2018	Sabilirasyad et al.	Crowd Management
2016	Mohamed et al.	Health and Well-being
2016	Nawaz et al.	Crowd Management
2014	Geabel et al.	Personal Safety Health and Well-being
2013	Yasin et al.	Crowd Management
2011	Hussain et al.	Crowd Management

Table 2: Published papers on Hajj and Sustainability

Year	Authors	Findings with relation to sustainability	Link to SDGs
2023	Karia and Saleh	Health and Well-being Logistics Management	SDG 3 SDG9
2022	Albalkhail and Al Amri	Health and Well-being Crowd Management	SDG 3 SDG 9
2022	Felemban and Ur Rehman	Transportation Management	SDG 11
2022	Abonomi et al.	Health and Well-being Social Sustainability	SDG 3 SDG 17
2021	Osra et al.	Circular Economy	SDG 12
2021	Lubis et al.	Customer Relationship Platform	SDG 10
2021	Al-Habaibeh et al.	Logistics Management	SDG 9
2020	Putri et al.	Customer Loyalty	SDG 10
2019	Rudyanto et al.	Health and Well-being	SDG 3

### 3. Results and Analysis

#### 3.1. Impact of AI on Hajj

The systematic literature review conducted to assess the impact of Artificial Intelligence (AI) on Hajj reveals significant insights into the evolving landscape of technology application in one of the largest annual religious gatherings. The analysis focuses on the frequency of different AI impacts identified in the literature (see Figure 2 below) and the year-wise distribution of these studies, providing a comprehensive understanding of the current state and potential future trends in this field. The temporal distribution of studies from 2011 to 2023 reveals a growing scholarly interest in the application of AI for Hajj.

The analysis underscores 'Crowd Management' as the most frequently cited AI application in the context of Hajj, with 13 instances. This finding is particularly poignant, reflecting the critical role AI plays in managing the extensive crowds that are characteristic of Hajj. The deployment of AI in crowd management not only enhances the efficiency of movement and safety protocols but also significantly contributes to the overall management of such a large-scale event. Following closely, 'Health and Well-being' emerged as the second most common theme, with 9 instances. This emphasis on health and safety is indicative of the increasing reliance on AI to monitor and ensure the welfare of pilgrims, especially in a setting prone to health risks and emergencies. AI applications in this domain range from health monitoring systems to emergency response mechanisms, highlighting a broad spectrum of technological interventions aimed at safeguarding pilgrim health. Other areas where AI's impact is noted, albeit less frequently, include 'Customer Satisfaction', 'Land Surface Temperature', 'Vehicle Detection', 'Logistics Management', and 'Personal Safety'. These varied applications demonstrate the multifaceted nature of AI's integration into the Hajj experience, extending beyond crowd and health management to address environmental monitoring, transportation, and overall pilgrim satisfaction.

The current trajectory suggests a continued and diversified application of AI in Hajj management. Given its dominant presence in the literature, AI-driven solutions for crowd management are likely to remain a primary research and development focus. This area presents opportunities for further innovation, especially in leveraging real-time data analysis and predictive modeling to enhance crowd control strategies. The increasing attention to health and well-being points to a future where AI could play a transformative role in healthcare management during Hajj. It is important to note that the emergence of diverse AI applications such as environmental monitoring and transportation management

indicates a trend toward a more holistic integration of AI in Hajj. Future research could expand into these less explored areas, potentially leading to a comprehensive AI-driven framework encompassing all aspects of the Hajj journey.

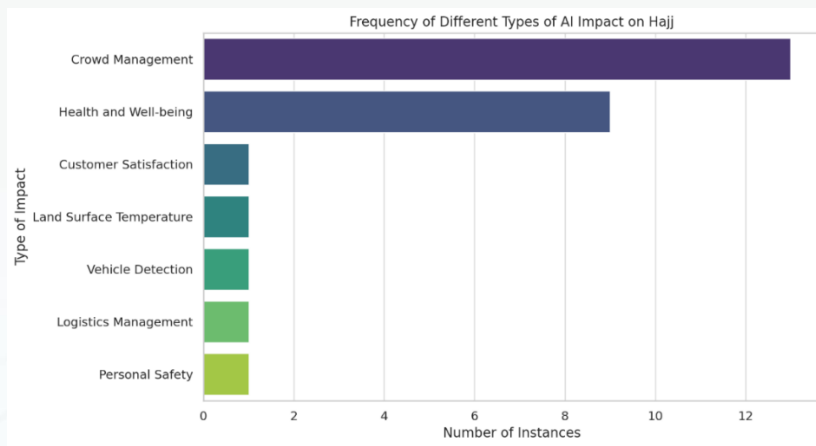


Figure 2: Most researched areas concerning AI for Hajj (Author, 2023)

### 3.2. Hajj and Sustainability

The analysis of Hajj-related research in the context of Sustainable Development Goals (SDGs) underscores a nuanced approach toward addressing the multifaceted challenges of this significant religious event. The predominant focus on SDG 3 (Good Health and Well-being) across multiple years reflects a deep-rooted concern for the health and safety of millions of pilgrims. This ongoing emphasis aligns with the critical need to manage health risks and ensure the well-being of attendees in an event of such scale and complexity.

In recent years, there has been a noticeable effort towards addressing broader sustainability issues (see Figure 3). The attention to SDG 10 (Reduced Inequalities) and SDG 12 (Responsible Consumption and Production) signifies a growing awareness of the social and environmental impacts of Hajj. These goals underscore the importance of equitable access to Hajj and sustainable management of resources, which are crucial for the long-term viability of the pilgrimage. The focus on SDG 11 (Sustainable Cities and Communities) and SDG 9 (Industry, Innovation, and Infrastructure) in later years reflects an understanding of the urban and infrastructural challenges posed by Hajj. These studies highlight the need for sustainable urban planning, efficient infrastructure, and innovative solutions to accommodate the unique demands of Hajj, ensuring it is a safe, inclusive, and sustainable experience. By broadening the research scope to encompass a wider array of SDGs, future studies can contribute to making Hajj not only a spiritually fulfilling journey but also encompass sustainability considerations, and this will be expanded on in the discussion chapter. For further information, the author provides the below, which defines SDG 3, 9, 10, 11, and 12.

**SDG 3: Good Health and Well-being** - This goal focuses on ensuring healthy lives and promoting well-being for all at all ages. It encompasses a wide range of targets, including reducing maternal mortality, ending preventable deaths of children under five years of age, fighting communicable diseases, promoting mental health, and ensuring universal health coverage.

**SDG 9: Industry, Innovation, and Infrastructure** - This goal aims to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. It highlights the role of infrastructure and innovation as crucial drivers of economic growth and development.

**SDG 10: Reduced Inequalities** - The focus here is on reducing inequality within and among countries. This includes addressing income inequality, promoting the social, economic, and political inclusion of all, and ensuring equal opportunities.

**SDG 11: Sustainable Cities and Communities** - This goal is about making cities and human settlements inclusive, safe, resilient, and sustainable. It involves investing in public transport, creating green public spaces, and improving urban planning and management in a way that is both participatory and inclusive.

**SDG 12: Responsible Consumption and Production** - The aim here is to ensure sustainable consumption and production patterns. It involves promoting resource and energy efficiency, sustainable infrastructure, and providing access to basic services, green and decent jobs, and a better quality of life for all.

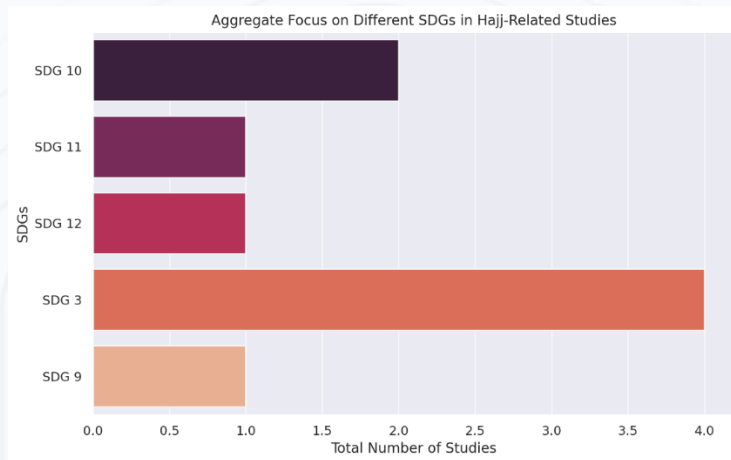


Figure 3: SDGs considered within published research on Hajj

#### 4. Discussion and Practical Implications

The analysis indicates progressive strides in AI research for Hajj, alongside inquiries into sustainability in this context. The deployment of Artificial Intelligence (AI) in Hajj operations offers a comprehensive means to address various Sustainable Development Goals (SDGs), augmenting the pilgrimage experience in line with global sustainability goals. About **SDG 3**, AI's critical role in health and well-being enhancement is evidenced by numerous studies (e.g. Karia and Saleh, 2023; Albalkhail and Al Amri, 2023). AI's capabilities in real-time health monitoring and predictive analytics are instrumental in managing pilgrims' health needs and pre-empting health hazards, including outbreaks of communicable diseases. Regarding **SDG 11**, AI's potential contribution to sustainable urban management during Hajj is noteworthy. AI-enabled crowd management (Binsawad and Albahar, 2022) and traffic systems (e.g. Felemban and Ur Rehman, 2022) are key in ensuring pilgrims' safe and efficient transit, aiding in sustainable urban planning and congestion reduction. Concerning **SDG 8**, AI's application in automating Hajj operations could enhance resource efficiency and open new economic avenues, indirectly boosting local economies through an improved tourism experience. Literature also highlights (e.g. Luo et al., 2023), under **SDG 9**, how AI integration in infrastructure management leads to resilient and sustainable infrastructure advancements, with AI-driven innovations enhancing Hajj-related services and infrastructure. For **SDG 12**, AI's role in optimizing resource use and waste reduction is significant (e.g. Shambour and Gutub, 2022), promoting sustainable consumption through data-driven management of critical resources like water and energy. With relation to **SDG 13**, AI's importance in environmental monitoring (e.g. Osra et al., 2021) is vital for evaluating and mitigating the



ecological impacts of Hajj, with predictive models being key in environmental risk assessment and climate change mitigation. Lastly, about **SDG 17**, collaborative AI ventures encourage partnerships among tech firms, governmental bodies, and global organizations, improving the Hajj experience and fostering international cooperation and knowledge exchange in managing large-scale religious gatherings (Abonimi et al., 2022).

To maximize AI's impact on Hajj and its contribution to SDGs, a holistic and integrated approach is essential. This involves deploying AI solutions in alignment with sustainability goals and fostering collaborative efforts (Karia and Saleh, 2023) among technology developers, Hajj authorities, and sustainability experts. Such an approach ensures that AI-driven solutions are innovative, socially responsible, economically viable, and environmentally sustainable. The synergy between AI and SDGs in the Hajj context exemplifies how technology can address complex global challenges, contributing significantly to community well-being and environmental stewardship.

## Conclusion

To sum up, this research aimed to lay out how AI could potentially revolutionize approaches toward addressing diverse sustainability issues linked to the Hajj. The culmination of this research provided an insightful roadmap for the integration of Artificial Intelligence (AI) in the context of Hajj, aligning technological advancement with the spiritual essence and sustainability imperatives of this significant pilgrimage. The systematic literature review, centering on the impact of AI on the Hajj pilgrimage and its sustainability considerations, reveals a landscape where technology meets tradition and innovation fosters sustainability. The analysis distinctly highlighted 'Crowd Management' and 'Health and Well-being' as the predominant AI applications in the Hajj context. The findings reflect a broader shift towards utilizing AI in enhancing the efficiency and safety of pilgrims, marking a significant stride in the modernization of Hajj operations while retaining its spiritual ethos. The focus on SDGs such as Good Health and Well-being, Reduced Inequalities, Responsible Consumption and Production, Sustainable Cities and Communities, and Industry, Innovation, and Infrastructure signals a comprehensive view of sustainability. The discussion section outlined further SDGs, which future research can tap into to maximize the sustainability footprint within the Hajj pilgrimage. The future of Hajj, as suggested by implications derived from this research, lies in the strategic amalgamation of AI and sustainability principles. This implementation of AI for Hajj to improve sustainability, while challenging, opens avenues for innovative solutions that harmonize the age-old traditions of Hajj with the imperatives of contemporary global challenges. In essence, this research lays the foundation for a future where the Hajj is not only a journey of spiritual significance but also a beacon of technological innovation and sustainability. A future improvement of this work is to expand on research conducted on the use of AI for sustainability. Future research should seek to align AI research within the Hajj context to different SDGs more tangibly and monitor the progression of these SDGs for an improved experience of this holy pilgrimage.

## References

- Abalkhail, A.A.A. and Al Amri, S.M.A. (2022). Saudi Arabia's Management of the Hajj Season through Artificial Intelligence and Sustainability. *Sustainability*, 14, 14142.
- Abonimi, A., De Lacy, T., Pyke, J. (2022). Environmental Impact of Hajj. *International Journal of Religious Tourism and Pilgrimage*, 10 (1), pp. 133-151.
- Albahr, M., Gazzawe, F., Thanoon, M. and Albahr, A. (2023). Exploring Hajj pilgrim satisfaction with hospitality services through expectation-confirmation theory and deep learning, *Heliyon*, 9(11), E22192.

- Algamdi, A. M. and Alghamdi, H. M. (2023). Instant Counting & Vehicle Detection during Hajj Using Drones, *Journal of Image and Graphics*, 11(2), pp. 204-211.
- AL-Ghamdi, A. S. A-M., Alshammari, S. M. and Ragab, M. (2023). Deep learning based face mask detection in religious mass gathering during covid-19 pandemic, *Computer Systems Science and Engineering*, 46(2), pp. 1863–1877.
- Al-Habaibeh, A., Hamadeh, S., Aljahdali, K. and Akib, S. (2020). Towards enhancing sustainability: A novel approach for reducing carbon emission during the transportation of Zamzam water by pilgrims during Hajj and Umrah, *Research in Transportation Business & Management*, 37, 100523.
- Alhameed, M. and Hossain, M. A. (2023). Rapid Detection of Pilgrims Whereabouts During Hajj and Umrah by Wireless Communication Framework: An application AI and Deep Learning," 2023 International Conference on Emerging Smart Computing and Informatics (ESCI), Pune, India, pp. 1-6, doi: 10.1109/ESCI56872.2023.10099969.
- Alharbey, R., Banjar, A., Said, Y., Atri, M., Alshdadi A. and Abid, M. (2022). Human faces detection and tracking for crowd management in hajj and umrah, *Computers, Materials & Continua*, 71(3), pp. 6275–6291, 2022.
- Alhazmi, E. S. Alraddadi, R. A. and Syed, L. (2021). Spatial Crowdsourcing for Social and Government Applications for Hajj-Umarah," 2021 1st International Conference on Artificial Intelligence and Data Analytics (CAIDA), Riyadh, Saudi Arabia, pp. 273-274, doi: 10.1109/CAIDA51941.2021.9425268.
- Al-Shaery, A. M., Aljassmi, H., Soha A., Farooqi, N. S., Al-Hawsawi, A. N., Moussa, M., Tridane, A. and Alam, Md. D. (2022). Real-Time Pilgrims Management Using Wearable Physiological Sensors, Mobile Technology and Artificial Intelligence, *IEEE Access*, vol. 10, pp. 120891-120900, doi: 10.1109/ACCESS.2022.3221771.
- Al-Shaery, A.M. Hejase, B. Tridane, A. Farooqi, N.S. and Jassmi, H.A. (2021). Agent-Based Modeling of the Hajj Rituals with the Possible Spread of COVID-19. *Sustainability*, 13, 6923.
- Binhotan, E.A. and Altameem, A. (2020). IoT-Based RFID Framework for Tracking, Locating and Monitoring the Health's Rituals of Pilgrims During Hajj. In: Luhach, A., Kosa, J., Poonia, R., Gao, XZ., Singh, D. (eds) First International Conference on Sustainable Technologies for Computational Intelligence. Advances in Intelligent Systems and Computing, vol 1045. Springer, Singapore. [https://doi.org/10.1007/978-981-15-0029-9\\_4](https://doi.org/10.1007/978-981-15-0029-9_4)
- Binsawad, M. and Albahar, M. (2022). A Technology Survey on IoT Applications Serving Umrah and Hajj", *Applied Computational Intelligence and Soft Computing*, ID 1919152, 10 pages. <https://doi.org/10.1155/2022/1919152>
- Elsheikh, A. E., Saba, A. I. Elaziz, M. A., Lu, S., Shanmugan, S., Muthuramalingam, T., Kumar, R., Mosleh, A. O., Essa, F. A. and Shehabeldeen, T A. (2021). Deep learning-based forecasting model for COVID-19 outbreak in Saudi Arabia, *Process Safety and Environmental Protection*, 149, pp. 223-233.
- Fallatah, A. and Imam, A. (2023) Detecting Land Surface Temperature Variations Using Earth Observation at the Holy Sites in Makkah, Saudi Arabia, *Sustainability*, 15(18):13355. <https://doi.org/10.3390/su151813355>
- Felemban, E., Sheikh, A.A. and Naseer, A. (2021). Improving Response Time for Crowd Management in Hajj. *Computers*, 10, 46.
- Felemban, E., Ur Rehman, F. (2022). An Interactive Analysis Platform for Bus Movement: A Case Study of One of the World's Largest Annual Gathering. In: Rodrigues, J.J.P.C., Agarwal, P., Khanna, K. (eds) IoT for Sustainable Smart Cities and Society. Internet of Things. Springer, Cham. [https://doi.org/10.1007/978-3-030-89554-9\\_6](https://doi.org/10.1007/978-3-030-89554-9_6)
- Geabel, A., Jastaniah, K., Hassan, R.A., Aljehani, R., Babadr, M., Abulkhair, M. (2014). Pilgrim Smart Identification Using RFID Technology (PSI). In: Marcus, A. (eds) Design, User Experience, and Usability. User Experience Design for Everyday Life Applications and Services. DUXU 2014. Lecture Notes in Computer Science, vol 8519. Springer, Cham. [https://doi.org/10.1007/978-3-319-07635-5\\_27](https://doi.org/10.1007/978-3-319-07635-5_27).
- Hussain, N., Yatim, H. S. M., Hussain, N. L., Yan, J. L. S. and Haron, F. (2011). CDES: A pixel-based crowd density estimation system for Masjid al-Haram, *Safety Science*, 49 (6), pp. 824-833.







## Exploring the impact of bed spacing during hajj season on missed nursing care and nurses' satisfaction (nurses' experience)

Hatan Alsubhi<sup>1\*</sup>, Ebtessam Elhihi<sup>2</sup>, Mohamed Shahid<sup>3</sup> and Mohamed Saleem<sup>4</sup>

1- Executive Administration of Nursing, KAMC, 2- Nursing Research and EBP Department, 3- Nursing Research and EBP Department, KAMC, 4- Department, Nursing Quality and Patient safety, KAMC

\*Corresponding author: E-mail (Al-subhi.H@kamc.med.sa)

## استكشاف تأثير المباعدة بين الأسرة أثناء موسم الحج على الرعاية التمريضية المفقودة ورضا الممرضات (تجربة الممرضات)

هتان الصبيعي<sup>1\*</sup>، ابتسام الهيبي<sup>2</sup>، محمد شاهد<sup>3</sup>، محمد سليم<sup>4</sup>

1- قسم إدارة التمريض بمدينة الملك عبد الله الطبية، مكة المكرمة، 2- قسم أبحاث التمريض بمدينة الملك عبد الله الطبية، مكة المكرمة، 3- قسم الجودة بالتمريض بمدينة الملك عبد الله الطبية، مكة المكرمة

### الملخص

الخلفية: أدى التخفيض التدريجي في أسرة المستشفيات، إلى جانب زيادة الهشاشة الاجتماعية والطبية التي تعيق الخروج من المستشفى، إلى نقص حاد في الأسرة. وقد أجبر هذا الأطباء على قبول المرضى في أجنحة غير مناسبة، مما أدى إلى خلق سيناريو يعرف باسم المباعدة بين الأسرة. على الرغم أن المباعدة بين الأسرة لها مزايا في تقليل أوقات الانتظار في قسم الطوارئ وتحسين قدرة المستشفى، إلا أنها تفرض أيضاً تحديات، مما يؤدي إلى نتائج سريرية أقل كفاءة.

طرق البحث: تم استخدام أسلوب البحث المختلط، والذي حاول استكشاف تجارب الممرضات في تقديم الرعاية للمرضى الذين يتبعون في الأسرة خلال موسم الحج. الدراسة شملت الموظفين الذين استقبلوا مرضى متباعدين في الأسرة خلال الفترة من 2023/6/23 إلى 2023/7/5.

النتائج: الكمية تشير إلى وجود فروق ذات دلالة إحصائية في الرعاية التمريضية المفقودة بين المجموعات متباعدة السرير وغير متباعدة السرير، مع إظهار درجات أعلى في السابق. تم تحديد جوانب محددة مثل الاستجابة لأضواء المكالمات والمساعدة في تلبية احتياجات استخدام المرحاض كمجالات تعاني من زيادة الرعاية المفقودة في المجموعة المتباعدة بين الأسرة.

وكشفت النتائج النوعية عن تسعة تحديات شملت: تحديات التواصل، والرعاية التمريضية المفقودة للمرضى المتباعدين في الأسرة، والعلاقة بين الرعاية المفقودة ونتائج المرضى، ومشاعر الممرضات خلال موسم الحج. كما تمت مناقشة استراتيجيات التعامل مع تحديات المباعدة بين الأسرة ومنع تفويت الرعاية التمريضية.

الاستنتاجات: سلطت هذه الدراسة الضوء على التعقيدات المحيطة بتباعد الأسرة خلال موسم الحج، مع التركيز على الحاجة إلى التواصل الفعال والموارد الكافية والاستراتيجيات الداعمة لضمان جودة رعاية المرضى ورضا الممرضين.

تلقي هذه الدراسة الضوء على التأثير المبي الكبير للنوبات الطويلة على طاقم التمريض أثناء الحج. تؤكد الزيادات في النتائج السلبية من بداية الحج وحتى نهايته على الحاجة إلى مزيد من البحث في تأثيرات العمل بنظام الورديات وتدعو إلى إعادة تقييم جداول عمل الممرضات لتعزيز رفاهيتهم والجودة الشاملة لرعاية المرضى أثناء الضغط العالي. الأحداث.

## Abstract

**Background:** The progressive reduction in hospital beds, coupled with increasing social and medical fragility hindering hospital discharge, has led to a severe shortage of beds. This has forced clinicians to admit patients to inappropriate wards, creating a scenario known as bed spacing. While bed spacing has advantages in reducing emergency department wait times and optimizing hospital capacity, it poses challenges, potentially leading to inferior clinical outcomes and inefficiency.

**Methods:** Mixed-methods research was employed; it attempted to explore nurses' experiences in providing care for patients who are bed-spaced during the Hajj season. All staff who received any bed-spaced' patient from June 23, 2023, to July 7, 2023, were included.

**Results:** Quantitative results indicate significant differences in missed nursing care between bed-spaced and non-bed-spaced groups, with the former exhibiting higher scores. Specific aspects, such as response to call lights and assistance with toileting needs, were identified as areas with increased missed care in the bed-spaced group. Qualitative findings revealed nine themes: communication challenges, missed nursing care for bed-spaced patients, the relationship between missed care and patient outcomes, and nurses' feelings during the Hajj season. Strategies were also discussed to cope with bed-spacing challenges and prevent missed nursing care.

**Conclusions:** This study sheds light on the complexities surrounding bed spacing during the Hajj season, emphasizing the need for effective communication, adequate resources, and supportive strategies to ensure quality patient care and nurse satisfaction.

This study sheds light on the substantial occupational impact prolonged shifts have on nursing staff during the Hajj. The increases in adverse outcomes from the start to the end of the Hajj emphasize the need for further research into shift work's effects and call for reevaluating nurse work schedules to enhance their well-being and the overall quality of patient care during high-stress events.

**Keywords:** Bed Spacing, Nurses' Experiences, Missed Nursing Care, Nurse Satisfaction

## 1. Introduction.

The reduction in hospital beds heightened social and medical fragility, and limited community healthcare services have led to a critical shortage of beds. [1] Clinicians are compelled to admit patients to clinically inappropriate wards, resulting in outliers—patients placed wherever there is a vacant bed, regardless of clinical appropriateness. This practice, known as bed spacing, aims to alleviate emergency department wait times and crowding, enhancing revenue by optimizing idle capacity. [2,3]. However, it burdens healthcare professionals and patients, potentially leading to inferior clinical outcomes and inefficiencies. [4]. Inexperience among nursing personnel in treating less prevalent diseases poses challenges, evidenced by significant differences in trauma patient care between specialized and non-specialized nursing. [5] Despite qualitative studies raising staff concerns about patient safety, the lack of quantitative data hinders comprehensive understanding. [3,6].

During the Hajj season in Saudi Arabia, hospitals face an influx of patients, leading to the utilization of bed spacing. While addressing bed shortages, this strategy may impact missed nursing care and nurse satisfaction. Nurse satisfaction is crucial for high-quality patient care, reduced burnout, and lower turnover rates. This study aims to explore the impact of bed spacing during the Hajj season on missed nursing care and nurses' satisfaction at King Abdullah Medical City, given the lack of prior studies on this matter in Saudi Arabia.

## 2. Methodology (Materials and methods)

**Research Design.** A mixed methods research design was used to conduct this study. It attempted to explore nurses' experiences providing care for bed-spaced patients during hajj season. Staff who received any bed spaced' patients from 23/6/2023 to 5/7/2023 were included. Staff nurses who were not present during data collection were excluded.

The sampling procedure involved a systematic approach to recruit nurses from both groups. Specifically, we identified and recruited 73 nurses who received bed-spaced patients and 73 nurses who attended to non-bed-spaced patients during the Hajj season. The process was designed to ensure that the number of nurses in each group was comparable to facilitate a meaningful comparison.

For nurses without bed spacing, we implemented a stratified random sampling method. We categorized the nurses based on relevant criteria such as specific units within the hospital. An equal number of nurses was randomly selected from each stratum to participate in the study. This approach aimed to minimize potential biases and ensure a representative sample of nurses who did not experience bed spacing during the specified period.

**Study Settings:** This study was carried out at King Abdullah Medical City, Holy Makkah that provides medical care for different patients with 390 active beds capacity. KAMC is one of Saudi Arabia's largest medical cities. It specializes in four core medical areas: oncology, cardiology, neuroscience, and specialized surgeries. KAMC has critical care units and medical-surgical units. It has specialized centers such as endoscopy, ophthalmology, and diabetes centers.

**Study Procedure:** The study, with KAMC IRB approval, secured nurses' cooperation through informed consent. An online questionnaire was distributed via email and WhatsApp, followed by qualitative data collection using structured questions. Ethical compliance included signed consent, audio-recorded interviews for transparency, ensuring anonymity, and allowing nurses to withdraw without consequences. Bed spacing was defined as patients admitted to unrelated departments for over 24 hours.

### Data Collection Tool

After the official approval from KAMC IRB. Data was collected through an online questionnaire that was developed by the researcher and semi-structured interviews. It includes three sections as follows:

#### Section I: Nurses' demographic and work-related characteristics.

The researcher developed this section to assess nurses' demographic and work-related characteristics. It includes gender, marital status, level of education, professional title, years of experience, age, and the department/clinic.

#### Section II: The Missed Nursing Care Survey.

This section was adopted from Williams 2009 [12]. This survey consists of two parts. **Part A** missed nursing care, and **Part B** for the reasons for missed nursing care. The first part consists of 24 items with a 5-point Likert-type scoring system (always missed, frequently, occasionally, rarely, and never missed). Cronbach's alpha value of the first part was 0.936, and the overall test–retest coefficient was 0.95. Each item in Kalisch et al.'s version is scored between 1 = rarely missed or never missed and 4 = always missed. The total score that can be obtained from the scale ranges between 24 and 96. High scores on the scale show increased missed care. **Part B** consists of 17 items related to the reasons for routinely missed nursing care and has a 4-point Likert-type scoring system (Not a reason for missed care, minor reason, moderate reason and significant reason). A higher score indicates a stronger reason for missed nursing care. Semi-structured interviews were conducted with nurses who had received bed-spacing patients during the Hajj season. Participants were recruited through purposive sampling. The sample size was determined by data saturation, which occurs when no new

information is obtained from additional participants. The data collection was audio-recorded and transcribed. This approach aims to gain insight into the experiences of staff nurses regarding the impact of bed spacing during hajj season on missed nursing care and nurses' satisfaction at King Abdullah Medical City. The present questionnaire comprises a set of 10 semi-structured interview questions.

### Statistical Analysis

Data was analyzed through SPSS package version 26. The categorical variables were expressed as numbers and percentages, while continuous variables were expressed as mean and standard deviation. Independent t-test was used to test the difference between two means of continuous variables. The ANOVA test was used to test the difference between more than two means of continuous variables. Statistically significant was considered at p-value < 0.05 & 0.01. Analyzing qualitative data entailed moving from raw, verbatim-recorded audio data through systematization to explanation and comprehension. The interview data was endeavored to explain the perspectives of individuals. The writing and identifying themes were required for data analysis, and classification was necessary for the themes. Labeling or coding made it possible to retrieve data associated with thematic concepts.

### 3. Results and Discussion

Table (1): Mean differences of missed nursing care reported by the studied nurses. (n=146)

Missed nursing care	Total	Non-Bedspaced. (n=73)	Bed paced (n=73)	Z	Sig
	Mean±SD				
1. Ambulation three times per day or as ordered	1.72±0.98	1.47±0.74	1.97±1.13	2.73	0.006
2. Turning patient every 2 hours	1.61±0.89	1.37±0.69	1.85±1.00	3.10	0.002
3. Feeding patient when the food is still warm	1.68±1.04	1.40±0.79	1.97±1.17	3.21	0.001
4. Setting up meals for patient who feeds themselves	1.55±0.87	1.37±0.75	1.74±0.94	2.68	0.007
5. Medications administered within 30 minutes before or after scheduled time	1.60±0.98	1.32±0.76	1.88±1.09	3.71	0.000
6. Vital signs assessed as ordered	1.42±0.86	1.32±0.79	1.53±0.91	1.87	0.06
7. Monitoring intake/output	1.26±0.64	1.27±0.71	1.25±0.57	0.31	0.75
8. Full documentation of all necessary data	1.40±0.83	1.36±0.82	1.45±0.85	0.81	0.41
9. Patient teaching about illness, tests, and diagnostic studies	1.49±0.88	1.38±0.86	1.59±0.89	1.87	0.06
10. Emotional support to patient and/or family	1.63±1.04	1.40±0.79	1.86±1.20	2.30	0.02
11. Patient bathing/skincare	1.43±0.80	1.22±0.58	1.64±0.93	3.37	0.001
12. Mouth care	1.62±0.97	1.37±0.71	1.86±1.12	2.7	0.005
13. Hand washing	1.40±0.83	1.32±0.79	1.48±0.86	1.65	0.09
14. Patient discharge planning and teaching	1.19±0.59	1.29±0.75	1.10±0.34	1.40	0.16
15. Bedside glucose monitoring as ordered	1.48±0.86	1.32±0.79	1.64±0.90	3.03	0.002
16. Patient assessments performed each shift	1.25±0.69	1.32±0.83	1.19±0.51	0.38	0.70
17. Focused reassessments according to patient condition	1.34±0.72	1.36±0.80	1.32±0.64	0.10	0.91
18. IV/central line site care and assessments according to hospital policy	1.41±0.77	1.32±0.78	1.51±0.76	2.12	0.03
19. Response to call light is initiated within 5 minutes	1.70±1.08	1.36±0.71	2.04±1.27	3.26	0.001



20. PRN medication requests acted on within 15 minutes	1.66±1.08	1.36±0.78	1.97±1.24	3.17	0.002
21. Assess effectiveness of medications	1.32±0.74	1.25±0.66	1.40±0.81	1.28	0.20
22. Attend interdisciplinary care conferences whenever held	1.69±1.03	1.40±0.72	1.99±1.20	2.96	0.003
23. Assist with toileting needs within 5 minutes of request	1.68±1.06	1.33±0.68	2.03±1.24	3.52	0.000
24. Skin/Wound care	1.39±0.80	1.19±0.46	1.59±0.99	3.5	0.01
Overall missed nursing care	1.49±0.65	1.33±0.59	1.66±0.68	3.20	0.001

**Table (1)** illustrates the overall missed nursing care among the studied nurses that was 1.49±0.65 which indicates low missed nursing care. There was a statistically significant difference between missed care for non-bed spaced and bed spaced p=0.001.

For the non-bed spaced group, the highest mean scores of missed nursing care were for ambulation of patients 3 times per day with a mean score 1.47±0.74 followed by feeding patient when the food is still warm, emotional support to patient and/or family and attending interdisciplinary care conferences whenever held with mean score (1.40±0.79, 1.40±0.79 and 1.40±0.72 respectively). The lowest mean score of missed nursing care was for skin/wound care, with a mean score of 1.19±0.46, followed by patient bathing/skin care and assessed the effectiveness of medications, with a mean score (of 1.22±0.58 and 1.25±0.66 respectively).

For the bed-spaced group, it was found that the highest mean scores of missed nursing care were for response to call light initiated within 5 minutes with a mean score of 2.04±1.27 followed by assist with toileting needs within 5 minutes of request with a mean score of 2.03±1.24 and attend interdisciplinary care conferences whenever held with mean score 1.99±1.20. At the same time, patient discharge planning and teaching had the lowest missed nursing care mean scores of 1.10±0.34.

Table (2): Mean differences of missed nursing care reasons as reported by the studied nurses.

Reasons of missed nursing care	Total	Non-Bed spaced		Z	Sig
		Mean±SD	Bedsaced		
Labor resources	2.72±0.98	2.96±0.98	2.47±0.93	3.09	0.002
1. Inadequate number of staff	2.97±1.18	3.25±1.17	2.70±1.12	3.16	0.002
2. Urgent patient situations (e.g., a patient's condition worsening)	2.48±1.15	2.79±1.13	2.16±1.10	3.29	0.001
3. Unexpected rise in patient volume and/or acuity on the unit	2.73±1.19	3.03±1.11	2.44±1.21	2.93	0.003
4. Inadequate number of assistive and/or clerical personnel (e.g., nursing assistants, techs, unit secretaries etc.)	2.68±1.15	2.85±1.16	2.52±1.13	1.77	0.07
5. Heavy admission and discharge activity	2.72±1.25	2.90±1.13	2.53±1.09	2.04	0.04
6. Unbalanced patient assignments	2.75±1.08	2.97±1.09	2.52±1.04	2.61	0.009
Communication/teamwork	2.28±0.87	2.34±0.91	2.23±0.82	0.79	0.42
7. Inadequate hand-off from previous shift or sending unit	2.20±1.04	2.29±1.06	2.11±1.02	1.03	0.29
8. Other departments did not provide the care needed (e.g., physical therapy did not ambulate)	2.46±1.02	2.45±1.06	2.47±0.98	0.10	0.91
9. Lack of back up support from team members	2.40±1.03	2.51±1.08	2.30±0.98	1.24	0.21
10. Tension or communication breakdowns with other ancillary / support departments.	2.32±1.03	2.38±1.04	2.26±1.01	0.77	0.43

11. Tension or communication breakdowns within the nursing team	2.27±1.03	2.25±1.03	2.29±1.04	0.21	0.83
12. Tension or communication breakdowns with the medical staff	2.22±1.04	2.22±1.04	2.22±1.05	0.05	0.95
13. Nursing assistant did not communicate that care was not provided	2.26±1.02	2.34±1.08	2.18±0.96	0.83	0.40
14. Caregiver off unit or unavailable	2.18±1.05	2.32±1.07	2.05±1.02	1.48	0.13
Material resources	2.52±0.94	2.54±1.00	2.51±0.90	0.25	0.79
15. Medications were not available when needed	2.37±1.03	2.36±1.07	2.38±1.00	0.19	0.84
16. Supplies/ equipment not available when needed	2.58±1.08	2.62±1.15	2.55±1.02	0.42	0.67
17. Supplies/ equipment not functioning properly when needed	2.64±1.05	2.66±1.10	2.62±1.00	0.28	0.78

Z: Mann-Whitney Test

**Table (2)** illustrates that there was a statistically significant difference between non bed spaced and bed spaced groups in relation to labor resources as the reason of missed nursing care  $p=0.002$ . **For the non-bed space and bed space groups**, the highest mean scores of missed nursing care reasons were for Labor resources, followed by Material resources and Communication/teamwork mean score.

### Qualitative results

We identified nine themes regarding the impact of bed spacing during hajj season on missed nursing care and nurses' satisfaction: 1) Communication with healthcare providers; 2) Missed nursing care for bed-spaced patients; 3) Relationship between missed nursing care and patient outcomes; 4) bed spaced patients and ability of care; 5) Relationship between missed nursing care and bed spaced patients; 6) Bed spaced patients and job satisfaction; 7) nurses' feelings during Hajj Season; 8) strategies to cope with bed spaced patients during Hajj Season; 9) Steps to prevent missed nursing care. Communication emerges as a central concern, with healthcare providers trusting on diverse tools such as intercom telephones, Bravo systems, and personal mobile phones to bridge the communication gap. The possibility of missed nursing care recognized to factors ranging from heavy workloads and skill gaps to the unavailability of physicians. Participants also supported the relationship between missed care and patient outcomes. Additionally, the study explores the impact of external factors, such as the Hajj season, on nursing care dynamics and job satisfaction. Skill development, strategies to cope during peak periods, and recommendations for preventing missed nursing care further enrich the narrative.

The study reveals low overall missed nursing care, attributed to effective communication, clear protocols, ongoing professional development, and technology implementation [1]. Bed-spaced patients exhibit more missed care, potentially due to differences in patient acuity, resource availability, communication challenges, and unit culture. Inadequate staffing emerges as a primary cause, increasing workload and patient-to-nurse ratio, supported by previous studies [7, 8]. Homogeneous characteristics of non-bed-spaced patient nurses may explain the lack of statistically significant differences. However, age and experience impact missed nursing care in bed-spaced patients, reflecting challenges in adaptation, communication, and mentorship [7, 8, 9]. Communication challenges persist, resonating with literature, and missed care correlates with adverse events [10, 11, 12]. Positive perceptions during Hajj suggest that improved staffing positively influences care [13]. Challenges align with existing research, and proposed strategies correspond with evidence-based recommendations, emphasizing the importance of addressing staffing, communication, and training issues in healthcare settings [14, 15, 16].

## Discussion

The exploration of the impact of bed spacing during the Hajj season on missed nursing care and nurses' satisfaction yielded several noteworthy findings. This study aimed to contribute insights into a unique context where, to the best of our knowledge, there is no existing research on the impact of bed spacing during the Hajj season on missed nursing care and nurses' satisfaction.

The result of this study revealed that the overall missed nursing care among the studied nurses was low. This may be related to effective communication and collaboration, clear protocols and standardized procedures, ongoing professional development and training programs, and technology implementation, such as electronic health records and effective time management. In the same context, the study of Alasmari et al. [14], who studied missed nursing care and its relationship with nurses' perceptions of the professional practice environment during Hajj Season, concluded that overall missed nursing care among the studied nurses was low missed nursing care.

There was a statistically significant difference between missed care for non-bed-spaced and bed-spaced spaced from nurses' perception in which bed-spaced patients have more missed care than non-bed-spaced patients. This may be due to the acuity and complexity of patients in non-bed space areas might differ from those in bed spaced areas, resource availability may vary between bed space and non-bed space areas, communication challenges that may differ between two settings and differences in units' culture and expectations may lead to variation in reported missed care reported.

The current study demonstrates that nurses reported that an inadequate number of staff was the leading cause of missing nursing care for non-bed-spaced and bed-spaced patients. This may be attributed to the shortage of staff often leading to an increased workload, increasing the likelihood of missed care, limiting time to attend to each patient's needs thoroughly and increasing the patient-to-nurse ratio. This result is congruent by Alasmari et al., [14] and Ibrahim and Abohabieb [15].

The result of this study indicated that no a statistically significant difference in missed nursing care for non-bed spaced patients in relation to characteristics of the studied nurses. This may be related to homogeneous nurse characteristics, consistent training and education and similar workload distribution. These findings are supported by Dutra et al. [16] who reported that missing nursing care was unrelated to nurses' age, gender, marital status, education, and experience. There was a statistically significant difference in missed nursing care for bed spaced patients in relation to age and years of experience. This may be related to less experience and familiarity with the healthcare environment, inability to adapt to workload, communication and coordination challenges and lack of mentorship and support. This result agreed with Alasmari et al., 14 who reported that the younger nurses had a higher mean score of missed nursing care. This reflects the nurses' inadequate experience that might aggravate during overload season such as Hajj season. Moreover, Ibrahim and Abohabieb [15] and Blackman et al. [17] stated a significant relationship between missed nursing care and nurses' age and experience. In contrast, a study done by Alasmari et al. [18] and Dutra et al. [16] revealed that there were no correlations between missed care and nurses' characteristics.

The findings highlight significant challenges in communication between healthcare providers, particularly when dealing with bed-spaced patients. This resonates with existing literature that emphasizes the importance of effective communication in healthcare [19]. In emergency situations, the lack of immediate access to responsible physicians can hinder timely decision-making and care provision [20]. The reliance on various communication tools, such as intercom telephones, Bravo systems, and personal mobile phones, may indicate a need for more streamlined and standardized communication protocols in healthcare settings [21].

The concerns expressed by participants regarding missed nursing care align with previous research emphasizing the impact of missed care on patient outcomes. A study by Kalisch et al., [22] found a direct correlation between missed nursing care and adverse events. The reasons cited for missed care, including heavy workloads and insufficient skills, are consistent with the literature on nursing workload and its implications for patient safety [23]. Strategies to reduce missed care, such as cross-training and proper time management, align with recommendations from Kalisch and Xie [24] for improving nursing care quality.

The positive perception of nurses during the Hajj season, attributed to increased staffing levels and improved staff-patient ratios, aligns with studies recognizing the impact of nurse staffing on patient outcomes [25]. The ability to provide better care during this period suggests that addressing staffing issues may contribute to improved patient care and job satisfaction.

The belief that handling bed spaced patients contributes to skill development is supported by literature emphasizing the role of diverse patient experiences in enhancing nursing skills and knowledge [26]. However, the challenges mentioned, such as staff shortages and high patient ratios, repeat existing research on the impact of these factors on nurse job satisfaction [27]. Efforts to address these challenges, as suggested by participants, may positively influence job satisfaction and overall quality of care.

The strategies proposed by participants align with evidence-based recommendations. Availability of physicians has been associated with improved patient outcomes [28]. Cross-training has been shown to enhance nurses' abilities and flexibility in managing diverse patient needs [29]. Additionally, the emphasis on proper communication, resource utilization, and seeking help aligns with studies promoting teamwork and collaboration in healthcare [30].

#### 4. Study limitations

While this study has contributed valuable insights into the impact of bed spacing during Hajj season on missed nursing care and nurses' satisfaction, several limitations should be considered. The relatively modest sample size of 146 nurses might constrain the generalizability of the findings to a broader nursing population. The study's focus on a specific healthcare setting during Hajj season may limit the extrapolation of results to different organizational contexts and cultural settings. Additionally, the reliance on self-reported data from nurses may introduce social desirability bias, potentially affecting the accuracy of reported levels of missed nursing care and nurses' satisfaction. Furthermore, the study primarily captured nurses' perceptions, with limited exploration of the patient perspective, potentially overlooking crucial insights into the overall quality of care. These limitations emphasize the need for caution when generalizing the findings and suggest avenues for more extensive, diverse, and longitudinal research to enhance further our understanding of missed nursing care and strategies for improvement in the unique context of Hajj season.

#### 5. Conclusions

This research sheds light on the critical implications of bed spacing during the Hajj season at King Abdullah Medical City. Quantitative findings highlight significant differences in missed nursing care between bed-spaced and non-bed-spaced groups, emphasizing the impact on patient care quality. Meanwhile, qualitative insights reveal communication challenges, the relationship between missed care and patient outcomes, and nurses' feelings during the high-demand Hajj period. The study underscores the need for effective communication, increased resources, and supportive strategies to address the occupational challenges faced by nurses. Furthermore, the study calls for a reevaluation of nurse work schedules to enhance their well-being and improve overall patient care quality during high-stress events. These findings

contribute valuable insights for healthcare providers and policymakers aiming to optimize care delivery and ensure nurse satisfaction during increased healthcare demand, such as the Hajj season.

## 6. Recommendations

Based on the research findings, several recommendations can be proposed to enhance nursing care and satisfaction during the Hajj season. To address the identified high missed nursing care in the bed-spaced group, there should be a focus on optimizing response times to call lights and assisting with toileting needs promptly. Special attention should be given to patient discharge planning and teaching, ensuring they receive comprehensive information before leaving. Furthermore, recognizing the impact of labor resources on missed care suggests a need for increased staffing during high-demand periods. Strategies to improve communication among healthcare providers, such as utilizing intercom telephones and Bravo systems, should be encouraged. Skill development programs and the implementation of coping strategies during peak periods can contribute to better nursing performance. Finally, the study highlights the importance of preventative measures to minimize missed nursing care, emphasizing the need for proactive planning and resource allocation during the challenging Hajj season.

## References

1. La Regina, M., Guarneri, F., Romano, E., Orlandini, F., Nardi, R., Mazzone, A., ... & Squizzato, A. (2019). What quality and safety of care for patients admitted to clinically inappropriate wards: a systematic review. *Journal of General Internal Medicine*, 34(7), 1314-1321.
2. Stylianou, N., Fackrell, R., & Vasilakis, C. (2017). Are medical outliers associated with worse patient outcomes? A retrospective study within a regional NHS hospital using routine data. *BMJ open*, 7(5), e015676.
3. Goulding, L., Adamson, J., Watt, I., & Wright, J. (2015). Lost in hospital: a qualitative interview study that explores the perceptions of NHS inpatients who spent time on clinically inappropriate hospital wards. *Health Expectations*, 18(5), 982-994.
4. Patel PB, Combs MA, Vinson DR (2014). Reduction of admit wait times: The effect of a leadership-based program. *Acad. Emergency Medicine* 21(3):266–273.
5. White BA, Biddinger PD, Chang Y, Grabowski B, Carignan S, et al. (2013). Boarding inpatients in the emergency department increases discharged patient length of stay *J Emerg Med* Jan;44(1):230–5.
6. Lloyd JM, Elsayed S, Majeed A, Kadambande S, Lewis D, Mothukuri R, et al. (2005). The practice of out-lying patients is dangerous: a multicentre comparison study of nursing care provided for trauma patients. *Injury*; 36:710–3.
7. Goulding, L., Adamson, J., Watt, I., & Wright, J. (2012). Patient safety in patients who occupy beds on clinically inappropriate wards: a qualitative interview study with NHS staff. *BMJ quality & safety*, 21(3), 218-224.
8. Liu, J., Griesman, J., Nisenbaum, R., & Bell, C. M. (2014). Quality of care of hospitalized internal medicine patients bedspaced to non-internal medicine inpatient units. *PloS one*, 9(9), e106763.
9. Gunnerson, K. J., Bassin, B. S., Havey, R. A., Haas, N. L., Sozener, C. B., Medlin, R. P., ... & Neumar, R. W. (2019). Association of an emergency department–based intensive care unit with survival and inpatient intensive care unit admissions. *JAMA network open*, 2(7), e197584- e197584.
10. Lord, K., Parwani, V., Ulrich, A., Finn, E. B., Rothenberg, C., Emerson, B., ... & Venkatesh, A. K. (2018). Emergency department boarding and adverse hospitalization outcomes among patients admitted to a general medical service. *The American Journal of Emergency Medicine*, 36(7), 1246-1248.
11. Leisman, D., Huang, V., Zhou, Q., Gribben, J., Bianculli, A., Bernshteyn, M., ... & Schneider, S. M. (2017). Delayed second dose antibiotics for patients admitted from the emergency department with sepsis: prevalence, risk factors, and outcomes. *Critical Care Medicine*, 45(6), 956-965.

12. Kalisch BJ and Williams RA. Development and psychometric testing of a tool to measure missed nursing care. *J Nurs Adm* 2009; 39(5): 211–219.
13. Lewins, A, Taylor, C & Gibbs, GR. (2005). What is qualitative analysis (QDA)? [Online] Available from: <http://www.qda.hud.ac.uk/Intro>
14. Alasmari, F. A., Ebrahim, E. A., Alhawsawi, H. Y., Abujaab, H. Z., Shahid, M. P., Alduaiji, N. A., ... & Tukruni, A. M. (2022). Missed Nursing Care and its relationship with Nurses' Perceptions of Professional Practice Environment during Hajj Season. *Evidence-Based Nursing Research*, 4(4), 77-86.
15. Ibrahim, I. A., Abohabieb E. E. (2020). Association between nursing work environment, patient safety culture, and missed nursing care among staff nurses. *Port Said Scientific Journal of Nursing*, 7(3), 265-284.
16. Dutra, C. K. D. R., Salles, B. G., & Guirardello, E. B. (2019). Situations and reasons for missed nursing care in medical and surgical clinic units. *Revista da Escola de Enfermagem da USP*, 53, e03470-e55475.
17. Blackman, I., Papastavrou, E., Palese, A., Vryonides, S., Henderson, J., & Willis, E. (2018). Predicting variations to missed nursing care: A three-nation comparison. *Journal of Nursing Management*, 26(1), 33–41.
18. Alasmari, F., Shahid, M., Tukruni, A., Alhawsawi, H., & Alhawsawi, H. Y. (2021). Missed nursing care and the predicting factors in Saudi Arabia. *American Journal of Nursing Research*, 9(4), 118-124.
19. Haig, K. M., Sutton, S., & Whittington, J. (2006). SBAR: A shared mental model for improving communication between clinicians. *Joint Commission Journal on Quality and Patient Safety*, 32(3), 167–175. [DOI: 10.1016/S1553-7250(06)32022-3]
20. Reader, T. W., Flin, R., Mearns, K., & Cuthbertson, B. H. (2011). Interdisciplinary communication in the intensive care unit. *British Journal of Anaesthesia*, 106(3), 378–385. [DOI: 10.1093/bja/aeq376].
21. Berg, L. M., Källberg, A. S., & Göransson, K. E. (2018). Communication in healthcare: A narrative review of the literature. *Healthcare*, 6(3), 89. [DOI: 10.3390/healthcare6030089]
22. Kalisch, B. J., Landstrom, G. L., & Hinshaw, A. S. (2009). Missed nursing care: A concept analysis. *Journal of Advanced Nursing*, 65(7), 1509–1517. [DOI: 10.1111/j.1365-2648.2009.04987.x]
23. Aiken, L. H., Clarke, S. P., Sloane, D. M., Sochalski, J., & Silber, J. H. (2002). Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. *JAMA*, 288(16), 1987–1993. [DOI: 10.1001/jama.288.16.1987]
24. Kalisch, B. J., & Xie, B. (2014). Errors of omission: Missed nursing care. *Western Journal of Nursing Research*, 36(7), 875–890. [DOI: 10.1177/0193945913518991]
25. Kane, R. L., Shamliyan, T. A., Mueller, C., Duval, S., & Wilt, T. J. (2007). The association of registered nurse staffing levels and patient outcomes: Systematic review and meta-analysis. *Medical Care*, 45(12), 1195–1204. [DOI: 10.1097/MLR.0b013e3181468ca3]
26. Lasater, K. B., Jarrín, O. F., Aiken, L. H., McHugh, M. D., & Sloane, D. M. (2016). Chronic hospital nurse understaffing meets COVID-19: An observational study. *BMJ Quality & Safety*, 30(8), 639–647. [DOI: 10.1136/bmjqs-2021-012529]
27. Lu, H., Zhao, Y., & While, A. (2019). Job satisfaction among hospital nurses: A literature review. *International Journal of Nursing Studies*, 94, 21–31. [DOI: 10.1016/j.ijnurstu.2019.02.013]
28. Landon, B. E., Wilson, I. B., Cohn, S. E., Fichtenbaum, C. J., Wong, M. D., Wenger, N. S., ... & Shapiro, M. F. (2012). Physician specialization and the quality of care for human immunodeficiency virus infection. *Archives of Internal Medicine*, 172(14), 1331–1337. [DOI: 10.1001/archinternmed.2012.2717]
29. Seymour, C. W., Iwashyna, T. J., Ehlenbach, W. J., Wunsch, H., & Cooke, C. R. (2017). Hospital-level variation in the use of intensive care. *Health Services Research*, 52(6), 2086–2104. [DOI: 10.1111/1475-6773.12569]
30. West, M. A., Borrill, C., & Unsworth, K. L. (2015). Team effectiveness in organizations. In G. P. Hodgkinson & J. K. Ford (Eds.), *International Review of Industrial and Organizational Psychology* (Vol. 30, pp. 181–232). John Wiley & Sons. [DOI: 10.1002/9781119211373.ch5]



## Enhancing Pilgrim Sleep Quality During Hajj: Effects of Indoor Environment on Sleep Staging

Ahmed Alqurashi<sup>1\*</sup>, Bader M Alqurashi<sup>2</sup>

1-Abdulrahman Fakieh Schools, 2- Department of Mathematics, Albaha University

\*Corresponding author: E-mail (ahmed.alqurashi2016@gmail.com)

### تحسين جودة النوم للحجاج خلال الحج: تأثير البيئة الداخلية على مراحل النوم

أحمد محمد القرشي<sup>1\*</sup>، بدرين مطير القرشي<sup>2</sup>

1- مدارس عبدالرحمن فقيه النموذجية، 2- قسم الرياضيات كلية العلوم جامعة الباحة

#### الملخص

الدراسات الطبية تظهر بشكل قاطع أن صحة الإنسان وسلوكه ورفاهيته العامة تتأثر بشكل كبير بجودة نومه. لذا، فهم المتغيرات التي تؤثر على جودة النوم أمر بالغ الأهمية. على الرغم من أن هناك العديد من الدراسات التي تناولت جودة النوم، إلا أنه لم يتم استكشاف العلاقة المعقدة بين ظروف النوم في مساكن الحجاج وجودة نومهم. وبناءً على ذلك، يهدف بحثنا إلى دراسة كيف يمكن للبيئات الداخلية للحجاج خلال موسم الحج أن تؤثر بشكل كبير على صحتهم العامة وجودة نومهم وقدرتهم على أداء واجباتهم الدينية. نحن نستخدم طريقة شاملة لمراقبة وتحسين جودة النوم عن طريق تقييم عناصر البيئة الداخلية المتنوعة بعناية لتحسين رفاة الحجاج طوال موسم الحج. بواسطة هذه الطريقة، يتم مراقبة الإضاءة والصوت ودرجة الحرارة والرطوبة في المكان بشكل مباشر. نحن نسعى إلى تحديد أي ارتباطات زمنية بين هذه العوامل البيئية وجودة نوم الحجاج من خلال التحقيق الشامل. نحن نعتمد تقنية مراحل النوم تستفيد من جهاز مراقبة محمول يُسمى "اليس بي دي إكس" لتقييم جودة النوم. بالإضافة إلى تحليل تشبع الأكسجين في الشرايين ومجهود التنفس وتدفق الهواء عبر الأنف ووضعية الجسم، يقدم. يستخدم الجهاز أيضاً أجهزة استشعار للتخطيط الكهربائي للقلب (ECG) والتخطيط الكهربائي للدماغ (EEG) والتخطيط الكهربائي للعضلات (EMG) والتخطيط الكهربائي للعين (EOG) لتسجيل معلومات حول عادات النوم. يمكننا تحديد العلاقات الكامنة عن طريق مقارنة المعلومات المجمعة من هذه الأجهزة مع البيئة الداخلية المرصودة. يساعد التحليل الوصفي في فهم كيف تؤثر العوامل البيئية على جودة النوم. لضمان أن الحجاج في أفضل حالة بدنية وعقلية خلال موسم الحج، يتم تحويل هذه الأفكار إلى نتائج وتوصيات يمكن للحجاج من خلالها إجراء تعديلات ناجحة على بيئة نومهم وتحسين جودة نومهم بشكل عام.

#### Abstract:

Medical study conclusively shows that a person's health, behavior, and general well-being are strongly impacted by the quality of their sleep, especially during the Hajj season. Understanding the variables influencing the quality of sleep thus becomes crucial. While several studies have looked at sleep quality, none have explored the complex relationship between the sleeping conditions in the lodgings used by Hajj pilgrims and the quality of sleep they get. Given this, the purpose of our research is to examine the ways in which pilgrims' interior environments during the Hajj season can have a major impact on their general health, quality of sleep, and capacity to carry out their religious obligations. We employ

a comprehensive method to monitor and improve sleep quality by attentively evaluating numerous indoor environmental elements to improve pilgrims' well-being throughout the Hajj season. With this method, the accommodations' light, sound, temperature, and humidity are all monitored in real time. We seek to determine any temporal relationships between these environmental factors and pilgrims' sleep quality through a thorough investigation. We apply a sleep staging technique that makes use of an Alice PDx portable monitoring device to evaluate the quality of sleep. In addition to arterial oxygen saturation, respiratory effort, nasal airflow, and body posture, this device offers noninvasive readings. The gadget also uses ECG, EEG, EMG, and EOG sensors to record information on sleeping habits. We can determine latent associations by comparing the information gathered from these devices with the observed interior environment. Descriptive analysis helps us understand how environmental influences affect the quality of our sleep. To ensure that pilgrims are in the greatest physical and mental condition for Hajj, these insights are then converted into actionable findings and recommendations for pilgrims to make successful adjustments to their sleep settings and enhance their overall sleep quality.

## 1. Introduction

Sleep is an important everyday activity that helps our bodies balance, regulate vital systems, and it is significant for logical decision making, perception, human interaction, and intelligence. It takes up about a third of our lives. Sleep is necessary for the brain's restorative functions and is linked to early brain development, learning, memory, and psychological well-being [1]. Stress reduction, hormone balance control, cardiovascular stability, and hunger regulation are all related to sleep functions. In other words, sleep deprivation or loss can have significant physical and emotional consequences [1]. As a result, measuring sleep quality has clinical relevance in detecting and diagnosing different sleep-related problems that have a negative impact on one's health. Subjective and objective techniques are used to measure and assess sleep quality. The automated identification of human sleep quality has been a focus of recent human-computer interface (HCI) research. Nowadays, Brain Computer Interface (BCI) is one of the major fields in computer science [2]. BCI is a communication system that takes bio-signals from a human's brain and analyzes them to measure brain activity and extract certain features from these signals to translate into output signals [3]. BCIs enable people with limited mobility to communicate and engage with their surroundings, allowing them to think and act more strategically. To increase engagement, a BCI should be able to identify a user's internal state and adjust to it in real-time [3]. Many fields can use BCIs, such as medical, education, security, entertainment, and neuromarketing. BCI has important and widespread applications in health care. The purpose of this study is to investigate persons' brain signals during the sleep processes to find the casual relationships with indoor (room) environmental factors to improve persons' sleep quality. Finding the environmental reasons for poor sleep quality could play an important role in detecting and diagnosing various sleep-related disorders. The indoor environment mainly includes the air quality (room temperature and humidity), sound and illumination levels. Also, one of our goals in this study is to explicitly answer the question of which of these four environmental factors negatively affect sleep quality the most by mining latent causal connectivity between the environmental variations and the sleep events. Our objectives include designing and developing an appropriate solution by applying computer science to explore how BCI can be designed and programmed to be useful in improving a person's sleep quality. In general, this study will record the participant's brain signals throughout their sleep, then change the environment in which they are sleeping to see how much it affects their sleep. This study's results will help users to choose the best room settings for better sleep quality. Furthermore, the study will help design the best environment and consider



the appropriate time for sleep. Finally, this research will add value to the field of computer science. This research started with an introduction that contains the statement of the problem, the purpose of the study, and the significance of the study. The following literature review explores existing research about related topics. In this literature review, previous studies were reviewed, and information was presented about this study's components. The next part of this study addresses the methodology, such as research design, research variables, population and sample, instrumentation and tool, data collection procedures, and data analysis. Then the results and findings for this study are presented. These results provide specific information about the descriptive and inferential statistical analysis. Finally, the last part of this research provides a summary of the findings. The contributions, limitations, implications, recommendations for future research, and conclusions are also discussed in this part.

## 2. Methodology (Materials and methods)

The study was conducted on 28 hours of sleep studies on 5 participants over a week. The participants were asked to sleep while having a conventional Polysomnography (PSG) [4] hook-up around their body, which includes a combination of brain signals, heartbeat, respiration, and body movements. We used a portable PSG device named Alice PDx portable monitoring device [5] with 4 EEG electrodes placed at the channels C4, F3, M1 and M2 (according to the International 10-20 system) on the scalp, in proximity to the right and left outer canthus, and over the chin, which were all referenced to two mastoids. This device, shown in Figure 1, individually acquired EEG, EOG, and EMG signals at a 256Hz sampling rate. Different sleep stages were scored every 30-second segment.



Figure 1: Alice PDx portable monitoring device

At the beginning of all studies, the sleeping room was set up to be quiet, dark, and cool. Necessary environmental data including light intensity, room temperature, air humidity, and acoustic signals are recorded. During sleep time, a list of different environmental changes was made derived from characteristics of how long and how often variations in the environment appear to influence sleep. Many properties of environmental variations were considered to bring more information about the causalities, that includes the amplitude, the duration, and the frequency of occurrence of the changes. All changes in these environmental factors were computed in the form of a time series. In this project, all environmental factors in the surrounding were collected without the user's consciousness. The environmental changes were detected and recorded via thermometer, hygrometer, and mobile built-in sensors. These factors are then characterized by the amplitude, the duration, and the frequency of occurrence of their change. Simultaneously, common measurements of sleep quality were recorded by PSG (figure 2). Recorded data from PSG is then clinically evaluated by sleep doctors in the sleep lab.



Figure 2: Participant under PSG study

The sleep quality assessment was made based on many factors include: Total recording time: is the time from when the light is turned off to when it is turned on. Total wake time: the total amount of time in which the sleeper awakens during the recording. Total sleep stage duration: is the total time of a particular sleep stage (i.e. Stages N1, N2, N3, and REM) divided by total sleep time. Periodic limb movements are involuntary limb movements. Respiratory events include apneas, hypopnea, and respiratory effort related arousals (RERAs) during sleep. Sleep events that happened during sleep (e.g., an occurrence of an awakening during sleep, a decrease of duration at REM stage, etc.) were subsequently inferred chronologically. Finally, latent relationships between the environmental changes and the sleep events were mined to generate a comprehensive sleep analysis. A descriptive analysis was next utilized to infer a deep insight into the correlation between environmental variations and sleep quality. Therefore, both explicit and implicit environmental causes of poor sleep quality overnight were determined. Eventually, appropriate comments can be provided to help the user improve the environment for better sleep. The overview of this study is shown in figure 3.

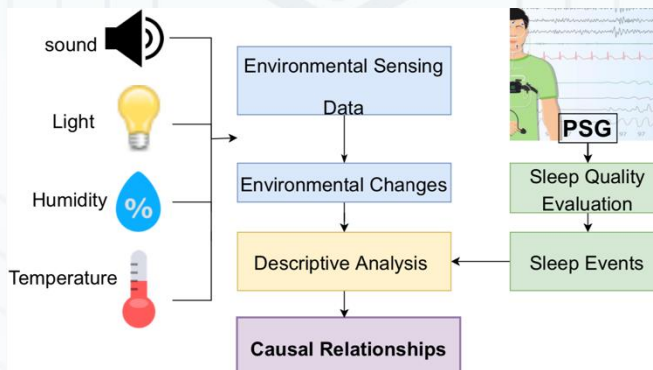


Figure 3: The study overview

### 3. Results and Discussion

There were five participants conducted 28 hours of sleep studies. The participants were two females (36 and 29 years old) and three males (45, 25, and 10 years old). The first male participant (178 cm tall, and weight 112 kilograms) slept for 5 hours. Both second (140 cm, and 47 kilograms) and third male participants (175 cm, and 85 kilograms) slept for 6 hours. The fourth participant was female (154 cm tall, and 63 kilograms) slept for 5 hours. The last female participant slept for 6 hours (160 cm, and 80 kilograms).

Table1: Information about the five participants: gender (G), Age (A), height (H), Weight (W), total sleep time (TST), sleep efficiency (SE), sleep onset latency (SOL), wake after sleep onset (WASO).

participant	G	A	H	W	TST	SE	SOL	WASO
1	Male	45	178	112	5	85.8 %	6.5	4.3
2	Male	10	140	47	6	83 %	2.2	36.5
3	Male	25	175	85	6	87.6 %	3.5	12.4
4	Female	36	154	63	5	80.4 %	3.2	7.2
5	Female	29	160	80	6	78.3 %	5.7	28.7

The sleep efficiency ranged between 78.3% and 87.6%. The first participant had a sleep efficiency (SE) of 85.8%. The second participant had a sleep efficiency of 83.0%. The third participant recorded the highest percentage of the SE (87.6%). The fourth and fifth participants had a sleep efficiency of 80.4% and of 78.3% respectively. The results showed that there were differences between participants in sleep onset latency. The longest period was recorded for the first participant who had a sleep onset latency (SOL) of 6.5 minutes, while the second participant had the least time with 2.2 minutes. The sleep onset latency for the third participant was 3.5 minutes and 3.2 minutes for the fourth participant. The fifth participant had 5.7 minutes (SOL). The first participant had a Wake-After-Sleep Onset (WASO) of 4.3 minutes. On the other hand, the second participant had a WASO of 36.5 minutes. The third, fourth, and fifth participants had wake after sleep onset of 12.4, 7.2, and 28.7 minutes, respectively. The PSG recorded common measurements of sleep quality. As we can see in (Figure 4) the signals show sleep stage duration (Wake, REM N1, N2, and N3 Stages). The participant started on the wake stage for a few minutes, then went to the N2 stage for a few minutes then went straight to the wake stage for a short period of time, then came back to N1 for a few minutes and then N2. Afterwards, the participant spent a long time in deep sleep moving between the N2 and N3 stages. Then participant stayed in the REM stage for a period. Afterward the participant went to the N2 stage, and then they went to the wake stage.

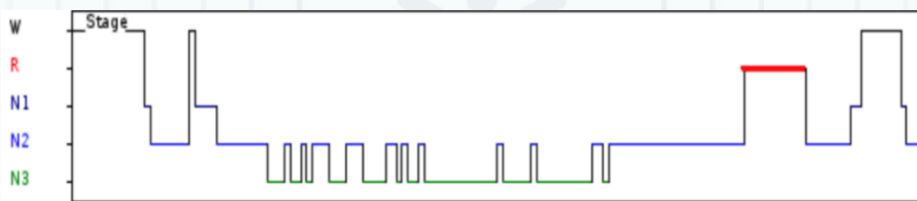


Figure 4: Sleep Study Summary

The results in (figure 5) show the relationship between sleep staging and the four environmental changes for participant number two and how each environmental change affected the sleep staging. (Figure 5) contains five parts. The first part is a chart that shows sleep stage duration (Wake, REM, N1, N2, and N3 Stages). The second part is a chart that shows the change in illumination levels throughout the sleep period. The change in noise level appears in the third part. The fourth part shows the change in temperature while the fifth part shows the change in humidity levels. It's noticeable in the chart that measures the illumination levels that the light was set to zero. When the illumination level jumped to around 120 LUX, the brain signals showed that the participant went from the N3 stage to the wake stage. That means that illumination level had a significant effect on the participant's sleep quality. Based on experimental results, the noise level dB was around 40 for most of the sleep period. When the noise level increased to around 70 dB immediately went from the N2 stage to the wake stage. That indicates there is a strong relationship between noise level and the participant's sleep quality since the increase in the noise level affected the sleep staging. The temperature was set at 20 degrees Celsius as shown in the fourth chart in Figure 5. Although during the sleep period sometimes the temperature was increased, this time it

was decreased to 15 degrees Celsius. During this time there was a clear change in the sleep stages. The participant went from the N2 stage to the wake stage. It was clearly seen that the change in temperature influences sleep staging.

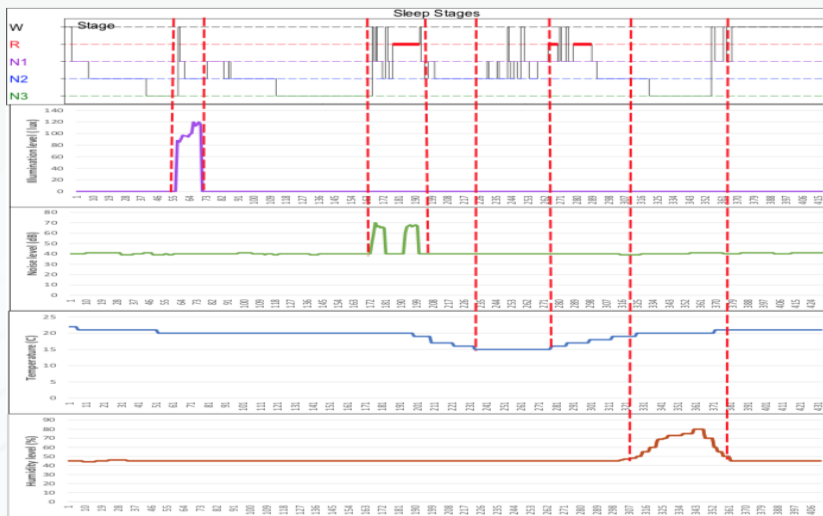


Figure 5: Second participant's sleep stages' signals with four environmental changes (illumination, noise, temperature, humidity)

The results indicated in the fifth chart in Figure 5 are the change in humidity. Throughout the sleep period, the humidity level was around 45%. Then, the humidity level increased to about 80%. When the humidity rose to 80%, the participant went from the N3 stage to the wake stage. It is clear that the change in humidity levels has an effect on sleep staging. In summary, we can clearly see in (figure 5) that the change in the four environmental factors (light, sound, temperature, humidity) had a significant effect on sleep quality because the change in the environmental factors caused a change in the sleep stages and waking. From these results of the five participants, I can reject the two null hypotheses when the result showed that the change in the four environments has a significant effect on sleep quality. Also, the results showed that the change in temperature and noise level has a bigger effect on sleep quality for pilgrims than the illumination level and humidity level. The sensations for temperature were different among participants. Short wakefulness has happened for some subjects when the room temperature dropped to 16° C. On the other hand, one of the subjects was discomfort when the room temperature increased to 23° C. For this participant, I found that in the higher temperature (around 23° C) the overall sleep time decreased, thus the sleep efficiency (SE) decreased too, and he woke several times during the sleep and stayed awake for a long period of time. Also, it was discovered that the length of REM stage was reduced for this subject. In General, room temperature has a significant impact on sleep quality. It was concluded that the most satisfying temperature between all participants was 20°C. Participants showed differences in their sensitivity relating to illumination level. For one of the participants, no significant difference or relationship was found between the lighting level and sleep events. In contrast, another subject was aroused suddenly during sleep when the room light turned on (light level became 88 immediately). In addition, the results showed that different people have different sensations of noise during sleep. In this study, it was considered that there are two types of ambient sounds during sleep: sudden and recurrent ambient sounds. Examples of sudden ambient sounds include sound from something falling and sound from opening and closing the door. Recurrent ambient sounds include sounds from outside, such as sounds from construction and cars in the roads. From the experiments I found that sudden sound had greater effect than recurrent ambient sound,

even though both sounds had some impact on the subjects' sleep quality. For the studies conducted in the sleep lab, noise was the most disruptive environmental factor during sleep, followed by lighting since the level of light was so high (more than 200 lux). The noise sources were sounds from the frequent opening and closing of doors, people outside the room, and hospital announcements. All participants showed discomfort when the humidity level increased more than 80% as well as when it decreased less than 30%. Therefore, it was concluded that humidity had the least impact on sleep quality. Understanding the challenges faced by pilgrims during the Hajj season, our findings reveal that noise emerges as the most significant environmental disruptor during sleep, closely followed by ambient temperature and humidity. The potential for considerable sleep disruption and insomnia arises, especially due to loud and frequent acoustic noise or elevated temperatures, adversely affecting both mental and physical health. Notably, high temperature and noise exhibit more substantial negative effects, establishing them as key environmental factors influencing sleep. Additionally, our study suggests that humidity has a comparatively lesser impact on sleep quality. However, it's essential to note that excessive humidity, surpassing the normal threshold of 30% to 50%, might negatively affect sleep quality. As pilgrims embark on their spiritual journey, addressing these factors becomes integral to promoting a restful and rejuvenating sleep experience.

#### 4. Discussion

There have been studies that suggest that people have a good night sleep in a room with a certain atmosphere, which is cool and quiet, dark, and has good air quality [6]. A warm atmosphere can have a negative impact on sleep quality [6, 7]. A room temperature of 16° C compared to 24° C resulted in an increase in total sleep duration and increased alertness in the morning. Also, sleeping in a cold environment for people with sleep apnea helps them sleep longer and more efficiently [6]. However, studies found that an extremely chilly environment can be more disruptive to sleep than a warm environment. Furthermore, the findings showed that excessive humidity mixed with heat might result in poor sleep quality [8]. Humidity can also damage patients' nasal passages. Furthermore, several investigations have shown that central apnea becomes considerably more prevalent as altitude rises and atmospheric pressure falls [9,10]. With increased sleep fragmentation, reduced slow-wave sleep, and higher arousal associated with periodic breathing, high altitude has a negative impact on sleep quality in individuals. Furthermore, studies showed that acoustic noise raises arousal levels, resulting in an increase in the waking stage and a decrease in N3 and REM stages. Sleeping with acoustic noise disrupts sleep, makes your sleep lighter, and can alter your body state when you get up. In addition, long periods of exposure to light, regardless of intensity, have been shown to decrease sleep quality [8]. The reason for this is that light produces all kinds of chemical reactions in the human body, causing physiological and behavioral changes [8]. The problem is that some of these environmental variables are readily apparent, while others are more difficult to detect. Furthermore, because people are unconscious when sleeping, they are unaware of environmental changes that may affect their sleep quality [9].

However, the research's paramount significance lies in determining the optimal sleeping conditions for the millions of pilgrims who annually converge in Makkah for the Hajj pilgrimage. Recognizing the physical and emotional demands of this sacred journey, it becomes crucial to provide a conducive environment for rest. The study's insights contribute to refining the overall pilgrimage experience by identifying key factors essential for creating an ideal sleeping atmosphere. This knowledge is instrumental in ensuring the well-being of pilgrims, allowing them to fully engage in the spiritual aspects of the Hajj without compromising their physical health.

In conclusion, the quest to identify the most suitable sleeping environment for pilgrims during the Hajj season underscores the commitment to enhancing the overall well-being of the millions who embark on this sacred journey each year. The findings of this research contribute not only to the comfort and recuperation of pilgrims but also to the successful facilitation of a spiritually enriching pilgrimage experience.

## 5. Conclusions

In the context of the Hajj season, where pilgrims face unique challenges, this study aimed to enhance the sleep quality of individuals by investigating brain signals during the sleep process and their connection to indoor (room) environmental factors. The findings revealed significant differences in Sleep Onset Latency (SOL) among participants, with high environmental temperatures identified as the primary cause of increased SOL, indicating a negative relationship between temperature and SOL.

On a positive note, the study identified that a room with a cold environment (around 20 °C), darkness (0 lux), quiet surroundings (less than 40 dB), and optimal humidity (around 45%) contributed to higher Total Sleep Time (TST) and Sleep Efficiency (SE) and lower SOL and number of awakenings.

Despite the valuable insights gained, the research faced certain limitations. The short duration of the sleep study experiments and the logistical challenges in coordinating participant schedules with the sleep lab were constraints. Additionally, technical issues arose when participants' movements caused PSG wires to disconnect, impacting the success of sleep experiments. The study's sample size was also a limiting factor.

For future endeavors, increasing the sample size, considering variations in gender and age related to sleep quality, and exploring more advanced PSG portable devices are proposed. Addressing these considerations will contribute to a more comprehensive understanding of the sleep-environment dynamics for pilgrims during the Hajj season.

## References

1. American Academy of Sleep Medicine. <http://www.aasmnet.org/>. Accessed: October 10, 2021.
2. Atkinson J, Campos D. Improving BCI-based emotion recognition by combining EEG feature selection and kernel classifiers. *Expert Systems with Applications*. 2016 Apr 1;47:35-41.
3. Al-Nafjan A, Hosny M, Al-Ohali Y, Al-Wabil A. Review and classification of emotion recognition based on EEG brain-computer interface system research: a systematic review. *Applied Sciences*. 2017 Dec;7(12):1239.
4. What Are Sleep Studies? <http://www.nhlbi.nih.gov/health/health-topics/topics/slpst/>. Accessed: October 10, 2021.
5. Grover, Sukhdev, Imran Bajwa, and Allyson R. Butchko. "Home Monitoring of Sleep Disorders." *Philips Respiration*(2009).
6. Xu, Xinbo, et al. "Five hypotheses concerned with bedroom environment and sleep quality: A questionnaire survey in Shanghai city, China." *Building and Environment* 205 (2021): 108252.
7. Lan, Li, et al. "Thermal environment and sleep quality: A review." *Energy and Buildings* 149 (2017): 101-113.
8. Zhang, Nan, Bin Cao, and Yingxin Zhu. "Indoor environment and sleep quality: A research based on online survey and field study." *Building and Environment* 137 (2018): 198-207.
9. Nguyen, Anh, et al. "mSleepWatcher: Why didn't I sleep well?." *ISSAT MCSE*(2015).
10. Zhang, Nan, Bin Cao, and Yingxin Zhu. "Effects of pre-sleep thermal environment on human thermal state and sleep quality." *Building and Environment* 148 (2019): 600-608.



## The impact of Health Excellence on Business Sustainability in the Hajj and Umrah: an analytical study from the point of view of health sector clients in Saudi Arabia

Nizar Raissi \*, Anas Hakeem

Finance Department, College of Business and Economics, Umm Al-Qura University

\*Corresponding author: E-mail (naraissi@uqu.edu.sa)

### أثر التميز الصحي على استدامة الأعمال في الحج والعمرة: دراسة تحليلية من وجهة نظر عملاء القطاع الصحي بالمملكة العربية السعودية

نزار الرايسي\*, أنس حكيم

قسم التمويل، كلية الإدارة والاقتصاد، جامعة أم القرى

#### الملخص

تهدف الدراسة لتحليل أثر التميز الصحي ورضا العملاء على استدامة الأعمال في قطاع الحج والعمرة بالمملكة العربية السعودية. وتتناول الدراسة استكشاف التحديات الصحية وتأثيرها على تجربة العملاء وكيفية تحسين هذه العلاقة لضمان استمرارية الأعمال. ولفهم طبيعة العلاقة بين مختلف متغيرات الدراسة اعتمد الباحث على المنهج الوصفي التحليلي، حيث تم جمع البيانات من خلال توزيع استبانة وجهت لحوالي 250 حاج ومعتمر. وتم تحليل البيانات باستخدام التحليل العاملي الاستكشافي والتوكيدي المعتمد على نمذجة المعادلات الهيكلية "البنائية"، وذلك لفهم العلاقة بين التميز الصحي، رضا العملاء، واستدامة الأعمال. وقد أظهرت النتائج أن هناك أثرا إيجابيا للتميز الصحي على استدامة الأعمال في القطاع من خلال تحفيز رضا العملاء وتعزيز الكفاءة التشغيلية لمقدمي الخدمات الصحية مما يضمن مستوى عال من الجودة. كما تبين أن الحجاج والمعتمرين يهتمون بالمحددات التالية: السلامة والتكنولوجيا، النظافة والتعقيم، التوعية والإرشاد الصحي، الاستجابة الفعالة للأزمات الصحية، وتجربة العملاء، وذلك مما يساهم في توفير بيئة صحية آمنة وموثوقة، وأن هذا يعزز إرضائهم وولائهم للخدمات المقدمة. وبناءً عليه، يُوصى الباحث بتعزيز التميز الصحي من خلال تحسين إجراءات السلامة والنظافة، وتكثيف التواصل المباشر مع العملاء لفهم احتياجاتهم الصحية بشكل أفضل، وتركيز الجهود لتحسين تجربة العملاء وتطوير الآليات الصحية التابعة لبرنامج خدمة ضيوف الرحمن، وبالتالي ضمان استدامة الأعمال في القطاع.

#### Abstract

The study examines the impact of Health Excellence and customer satisfaction on Business Sustainability in the Saudi Arabian Hajj and Umrah sector. It explores health challenges' influence on customer experience and suggests ways to enhance this relationship for business continuity. Employing a descriptive analytical method, data from 250 pilgrims were collected through a questionnaire. Utilizing structural equation modeling (SEM), the study conducted exploratory and confirmatory factor analysis to reveal the connections between Health Excellence, Customer Satisfaction, and

business sustainability. Results indicate a positive impact of Health Excellence on business sustainability by fostering customer satisfaction and improving Health Service Providers' operational efficiency. Pilgrims prioritize safety, technology, hygiene, health awareness, effective crisis response, and client experience. These factors contribute to a secure health environment, heightening satisfaction and loyalty. Recommendations include improving safety and hygiene protocols, enhancing direct communication with customers to understand their health needs, and refining the Pilgrims Experience Program for overall customer satisfaction and loyalty, ensuring sustained business success in the Hajj and Umrah sector.

**Keywords:** Health excellence, customer Satisfaction, business sustainability, customer experience, Pilgrims Experience Program.

### 1. Introduction

The Saudi Arabian Hajj and Umrah sector plays a pivotal role in the global pilgrimage industry, attracting millions of visitors annually. As the demand for religious tourism continues to rise, ensuring the health and satisfaction of pilgrims becomes paramount for the sustained success of businesses operating in this sector. This study delves into the interplay between Health Excellence, customer satisfaction, and business sustainability, shedding light on the intricate dynamics that influence the overall experience of pilgrims. Informed by contemporary research on customer satisfaction in tourism and healthcare industries (Smith et al., 2018; Parasuraman et al., 2020), the paper employs a descriptive analytical method to collect data from 250 pilgrims. The subsequent application of structural equation modeling enables a comprehensive exploration of the relationships between Health Excellence, Customer Satisfaction, and business sustainability. By focusing on the nuanced preferences and priorities of pilgrims, this research aims to contribute valuable insights to the strategic enhancement of health services, customer engagement, and overall business continuity in the unique context of the Hajj and Umrah sector. In addressing the evolving landscape of pilgrimage experiences, this study draws on recent works such as Al-Aboudi, N. N. (2023) and Rahman et al. (2021), emphasizing the contemporary relevance of Health Excellence and customer satisfaction in shaping sustainable business practices. The research navigates the complex intersection of healthcare and tourism, offering insights that are timely and applicable to the dynamic challenges faced by businesses in the Saudi Arabian Hajj and Umrah sector. Based on the predefined studies we have illustrated in figure 1 the conceptual research model.

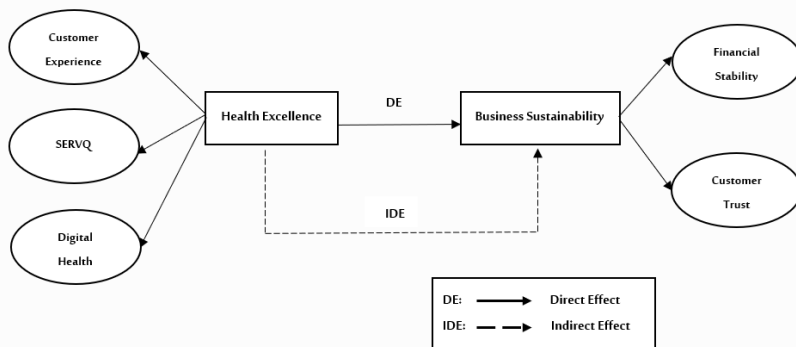


Figure 12. Conceptual research model

### 2. Methodology (Materials and methods)

To comprehensively investigate the impact of Health Excellence and customer satisfaction on Business Sustainability in the Saudi Arabian Hajj and Umrah sector, a rigorous methodology was employed. The study utilized a descriptive



analytical approach, collecting data from 250 pilgrims through a structured questionnaire. The questionnaire was designed based on established models and frameworks in tourism and healthcare research, ensuring a robust foundation for data collection (Smith et al., 2018; Parasuraman et al., 2020). Pilgrims were selected through a systematic sampling method, considering demographic diversity and pilgrimage experience. The gathered data underwent thorough analysis using structural equation modeling (SEM), incorporating both exploratory and confirmatory factor analyses. This method allowed for a nuanced examination of the relationships between Health Excellence, Customer Satisfaction, and business sustainability. The structural equation modeling approach provides a quantitative lens to explore the intricate connections between variables, contributing to the empirical understanding of the complex interplay within the unique context of the Hajj and Umrah sector. Through this methodological framework, the study aims to offer actionable insights for stakeholders to enhance health services, customer satisfaction, and overall business sustainability in the sector.

### 3. Results and Discussion

Results confirm item validation and reliability with Cronbach's Alpha exceeding 90%, indicating high consistency among constructs. Internal coherence and satisfactory reliability coefficients are evident in tested variables. Normality tests (Skewness and Kurtosis) support item validity, falling within -1 to +1 range. Measurement scale validation involves representative item calculation (loading) via Total Variance Explained (TVE). KMO and Bartlett's tests show statistical significance above 91.7%, with a construct p-value of 0.000, reflecting high significance. Variance analysis underscores item and factor validation, exceeding 72% for the five latent variables.

Table 1. Exploratory factor analysis for measurement scales

Variables	Code	N of Items retained	Cronbach's Alpha	KMO and Bartlett's Test		Total Variance Explained (Cumulative %)
				Kaiser-Meyer-Olkin Measure	Bartlett's Test (Sig.)	
Customer Experience	CX	6	0.912	0.917	0.000	72.475
Service Quality	SQ	4	0.949			
Digital Health	DH	4	0.876			
Customer Trust	TR	2	0.931			
Financial Stability	FS	7	0.968			

The evaluation of reflective measurement models commenced with reliability and validity tests of items relative to their latent variables. Findings indicate a Cronbach's indicator exceeding 0.85, ranging between [0.876; 0.958], demonstrating satisfactory item consistency within each construct. The second criterion, Jöreskog's Rhos, surpasses 92.4%, significantly exceeding the 0.6 threshold. These statistical indicators affirm the internal coherence of 17 items, highlighting strong consistency between items and constructs. The significant values of the tested criterion validate items as measurement scales for the research model.

Table 2. The reliability and validity of constructs

Constructs	Code	N of Items	Cronbach's Alpha	Jöreskog's Rhos	Average Variance Extracted (AVE)
Customer Experience	CX	4	0.901	0.927	0.720
Service Quality	SQ	4	0.950	0.964	0.869
Digital Health	DH	3	0.876	0.924	0.801
Customer Trust	TR	1	1.00	1.00	1.00
Financial Stability	FS	5	0.958	0.968	0.857

The statistical significance of the correlation between constructs was confirmed at a critical threshold of 5% (p-value < 0.05) in most relationships. Additionally, the total effects outcome indicates a direct relationship among all variables, except for the relationship between SERVQ, financial stability and customer trust which demonstrated an indirect effect.

Table 3. The estimates of path coefficients

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics ( O/STDEV )	P Values
Customer Experience -> Customer Trust	0.388	0.415	0.168	2.308	0.021*
Customer Experience -> Financial Stability	0.406	0.436	0.155	2.620	0.009*
Digital Health -> Customer Trust	0.470	0.445	0.180	2.618	0.009*
Digital Health -> Financial Stability	0.652	0.636	0.161	4.041	0.000*
SERVQ -> Customer Trust	0.060	0.045	0.157	0.379	0.705
SERVQ -> Financial Stability	-0.139	-0.162	0.149	0.933	0.351

Note: \* p < .05

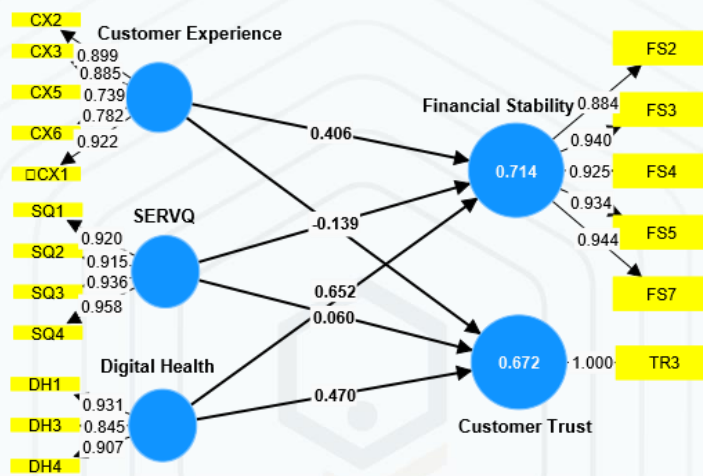


Figure 2. The structural model with estimated parameters

Table 4. The significance analysis of the Direct and Indirect Effects

Hypotheses	Path	Direct (DE)/Indirect effects (IDE)/NR	t-values	p-values	Outcome	H0 validation
H1 The greater customer experience within organisations, the more effective it will be on financial stability	CX -> FS	DE	2.620	0.009*	Yes	Accepted
H2 The greater customer experience within organisations, the more effective it will be on customer trust	CX -> TR	DE	2.308	0.021*	Yes	Accepted
H3 The greater the SERVQ, the more financial stability it will contribute on the business sustainability	SQ -> FS	IDE	0.933	0.351	No	Rejected with DE (Accepted in IDE)
H4 The greater the SERVQ, the more customer trust it will contribute on the business sustainability	SQ -> TR	IDE	0.379	0.705	No	Rejected with DE (Accepted in IDE)
H5 The greater Digital health in organisations, the more effective it will be on financial stability	DH -> FS	DE	4.041	0.000	Yes	Accepted

H6	The greater Digital health in organisations, the more effective it will be on customer trust	DH -> TR	DE	2.618	0.000	Yes	Accepted
----	--	-------------	----	-------	-------	-----	----------

Note: \*  $p < .05$ , estimated using the latent variable scores of the constructs.

Table 4 presents a comprehensive analysis of the direct (DE) and indirect effects (IDE) associated with various constructs in the study. The focus lies on understanding the impact of customer experience (CX), SERVQ (SQ), and Digital Health (DH) on financial stability (FS) and customer trust (TR). The results reveal statistically significant direct effects for CX on both FS and TR, emphasizing its influential role. However, for SERVQ, the indirect effects show significance in contributing to FS and TR, despite the rejection of direct effects. Digital Health exhibits substantial direct effects on both FS and TR, underscoring its significant influence in organizational contexts. The outcomes provide valuable insights into the intricate relationships between these constructs and their implications for financial stability and customer trust within organizations.

#### 4. Conclusions

In conclusion, this study illuminates the intricate dynamics between customer experience (CX), SERVQ, Digital Health (DH), financial stability (FS), and customer trust (TR) within organizational contexts. The findings underscore the pivotal role of customer experience in fostering both financial stability and customer trust, emphasizing its multifaceted impact on organizational success. Despite the nuanced complexities, the indirect effects of SERVQ contribute significantly to financial stability and customer trust, unveiling a subtler but substantial influence in the realm of business sustainability. Furthermore, Digital Health emerges as a potent catalyst, exhibiting robust direct effects on both financial stability and customer trust, signaling its paramount importance in contemporary organizational landscapes.

These insights not only contribute to the theoretical understanding of the interplay between healthcare, customer relations, and organizational outcomes but also offer practical implications for businesses in the Saudi Arabian Hajj and Umrah sector. As organizations strive for resilience and sustained success, the recommendations derived from this study, including refining safety protocols, enhancing customer communication, and optimizing the overall customer experience program, serve as actionable pathways for stakeholders to navigate the evolving landscape of religious tourism with agility and foresight.

#### 5. Recommendations

In light of the study's findings, several strategic recommendations emerge for stakeholders in the Saudi Arabian Hajj and Umrah sector. Firstly, there is a pressing need to enhance safety protocols, incorporating advanced technologies to ensure a secure and hygienic pilgrimage environment. Direct communication channels with pilgrims should be intensified to better understand their evolving health needs and concerns. Additionally, refining the Pilgrims Experience Program is crucial, focusing on technological integration, health awareness initiatives, and effective crisis response mechanisms. Strengthening collaboration between health service providers and digital health platforms is essential for optimizing operational efficiency and ensuring a seamless integration of health excellence into the pilgrimage experience.

These recommendations collectively contribute to elevating customer satisfaction, loyalty, and the overall sustainability of businesses in the sector. As the pilgrimage landscape evolves, embracing innovative approaches to health services and customer engagement is not only a strategic imperative but also a testament to the commitment to ensuring the well-being and satisfaction of pilgrims, fostering a resilient and prosperous future for the Hajj and Umrah sector.

## References

- Al-Aboudi, N. N. (2023). The Role of Scenario Planning in Achieving Strategic Foresight. *Migration Letters*, 20(S3), 626-640.
- Grewal, D., Herhausen, D., Ludwig, S., & Ordenes, F. V. (2022). The future of digital communication research: Considering dynamics and multimodality. *Journal of Retailing*, 98(2), 224-240
- Hair, J. F., Hult, G. T. M., Ringle, C. M., and Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. 2nd Ed. Thousand Oaks, CA: Sage.
- Hair, J.F., Risher, J.J., Sarstedt, M. and Ringle, C.M. (2019), "When to use and how to report the results of PLS-SEM", *European Business Review*, Vol. 31 No. 1, pp. 2-24. <https://doi.org/10.1108/EBR-11-2018-0203>
- Hair, J.F., Risher, J.J., Sarstedt, M. and Ringle, C.M. (2019), "When to use and how to report the results of PLS-SEM", *European Business Review*, Vol. 31 No. 1, pp. 2-24. <https://doi.org/10.1108/EBR-11-2018-0203>
- Karami, M. and Tang, J. (2021), "Decision-makers' logic of control and SME international performance", *Journal of Business & Industrial Marketing*, Vol. ahead-of-print No. ahead-of-print. <https://doi.org/10.1108/JBIM-11-2020-0516>
- McKenny, A.F., Aguinis H., Short, J.C., Anglin, A.H., (2018). What doesn't get measured does exist: Improving the accuracy of computer-aided text analysis. *Journal of Management*, 44 (7), pp. 2909-2933, 10.1177/0149206316657594
- Merhi, M., Harfouche, A. (2023). "Enablers of Artificial Intelligence Adoption and Implementation in Production Systems", *International Journal of Production Research*, Accepted paper, In press (FNEGE 2; SJR=2.78; Q1 in Industrial and Manufacturing Engineering) <https://doi.org/10.1080/00207543.2023.2167014>
- Rahman, H. U., Zahid, M., & Khan, M. (2022). Corporate sustainability practices: a new perspective of linking board with firm performance. *Total Quality Management & Business Excellence*, 33(7-8), 929-946.
- Smith, M. S., Cook, C., Sokona, Y., Elmqvist, T., Fukushi, K., Broadgate, W., & Jarzebski, M. P. (2018). Advancing sustainability science for the SDGs. *Sustainability science*, 13, 1483-1487.



## Health Impacts of Air Pollution during a short-term event (Hajj)

Omar B. Ahmed<sup>1\*</sup>, Turki M. Habeebullah<sup>1&2</sup>

1-Department of Environmental and Health Research, The Custodian of the Two Holy Mosques Institute for Hajj and Umrh Research, Umm Al-Qura University, 2- General Manager for Research, Development and Innovation - National Center for Meteorology (NCM) - Saudi Arabia.

\*Corresponding author: E-mail (abuaglah1@hotmail.com)

### الآثار الصحية لتلوث الهواء خلال فترة الفعاليات القصيرة (الحج)

عمر بشير احمد<sup>1\*</sup>، تركي محمد حبيب الله<sup>2&1</sup>

1- قسم البحوث البيئية والصحية، معهد خادم الحرمين الشريفين لأبحاث الحج والعمرة، جامعة أم القرى، مكة المكرمة، 2- الادارة العامة للبحث والتطوير والابتكار - المركز الوطني للأرصاد- المملكة العربية السعودية.

#### الملخص

أثناء التجمعات الجماهيرية (الحج)، يتجمع ملايين الأشخاص بصورة كثيفة، وبالتالي فإن تلوث الهواء قد يزيد من خطر الإصابة بالأمراض. تهدف الدراسة الحالية إلى تقييم التأثيرات قصيرة المدى للملوثات الجسيمات ذات التركيز 10 والجسيمات ذات التركيز 2.5 وغاز ثاني أكسيد النيتروجين وغاز الأوزون على الحجاج أثناء موسم الحج. استخدمت الدراسة برنامج AirQ+1.3v لتقدير تقييم تأثير تلوث الهواء بسبب التعرض قصير المدى للملوثات الجسيمات ذات التركيز 10 والجسيمات ذات التركيز 2.5 وغاز الأوزون وغاز ثاني أكسيد النيتروجين في الهواء المحيط بمدينة مكة المكرمة. وأظهرت النتائج أن متوسط تركيزات ملوثات الجسيمات ذات التركيز 10 والجسيمات ذات التركيز 2.5 وغاز الأوزون وغاز ثاني أكسيد النيتروجين في الهواء المحيط بمدينة مكة المكرمة. وأظهرت النتائج أن متوسط تركيزات ملوثات الجسيمات ذات التركيز 10 والجسيمات ذات التركيز 2.5 وغاز الأوزون وغاز ثاني أكسيد النيتروجين كان 12.86، 118.9، 14.86، و 24.71 ميكروجرام/م<sup>3</sup> على التوالي. وأوضحت الدراسة أن ثلاث حالات وفاة للحجاج يمكن أن تكون ناجمة عن التعرض قصير المدى لتركيز ثاني أكسيد النيتروجين وهو 24.7080 ميكروجرام م<sup>3</sup>. وبينت النتائج أن أعلى التأثيرات التي قدرت أثناء فترة الحج كانت مرتبطة بحالات الوفاة بسبب ارتفاع ثاني أكسيد النيتروجين والتي تقرب من 3 حالات من إجمالي الحالات. ووفقاً لتقديرات نموذج AirQ+، فإن أعلى نسبة مئوية كانت مرتبطة بالوفيات عند التعرض لثاني أكسيد النيتروجين كانت بقيمة 0.4% بينما كانت النسبة المنسوبة من إجمالي وفيات الحجاج المرتبطة بجميع ملوثات الجسيمات ذات التركيز 10 والجسيمات ذات التركيز 2.5 وغاز الأوزون هي 0.0% من إجمالي حالات النتائج العامة. وفقاً لتقديرات نموذج AirQ+، فإن أكبر عدد من الحالات الصحية لكل 100.000 من السكان بسبب التعرض لـ PM2.5 و PM10 و O3 و NO2 كان بقيمة 0 و 0.01 و 0.14 على التوالي. وكانت أيضاً نسبة الخطر الناتجة عن التعرض لـ PM2.5، PM10، O3، NO2 بقيمة 1.0123، 1.028، 1.0029، و 1.0027 على التوالي. واختتمت الدراسة أن هناك قلة في معدل الوفيات بسبب تركيز ملوثات الهواء خلال فترة الحج القصيرة. أشارت نتائج هذه الدراسة إلى ضرورة تحسين جودة الهواء الخارجي في مدينة مكة المكرمة خاصة أثناء التجمعات الجماهيرية. وتوصي بدراسة عبء تلوث الهواء على المدى الطويل الناجم عن الأمراض في مكة المكرمة والمدينة المنورة بالمملكة العربية السعودية.

#### Abstract

During mass gatherings (pilgrimage), where millions people totally gathered, air pollution may increase the risk of developing diseases. The present study aimed to evaluate the short-term impacts of PM10, PM2.5, NO2, and O3 pollutants on the pilgrims during Hajj (Pilgrimage) event. The study used AirQ+1.3v to estimate the impact assessment

of air pollution attributed to short-term exposure to PM<sub>10</sub>, PM<sub>2.5</sub>, O<sub>3</sub>, and NO<sub>2</sub> in ambient air in the city of Makkah. The results showed that the average concentrations of PM<sub>10</sub>, PM<sub>2.5</sub>, O<sub>3</sub>, and NO<sub>2</sub> was found to be 12.86, 118.8917, 14.86, and 24.71 µg/m<sup>3</sup> respectively. According to the estimates of AirQ+ model, the highest attributable proportion percentage was related to mortality to NO<sub>2</sub> with the value of 0.4. Three cases of mortality for pilgrims could be caused by short-term exposure to the concentration of NO<sub>2</sub> is 24.7080 µg m<sup>-3</sup>. The highest impacts estimated in hajj event was related to all cases of mortality attributable to NO<sub>2</sub> with almost 3 cases from the total cases of this outcome. The attributable proportion of total mortality of pilgrims associated with all of PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub> was 0.0 % of total cases of this outcome. According to the estimates of AirQ+ model, the highest number of attributable cases per 100,000 populations was caused by exposure to PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub> with the value of 0, 0, 0.01, and 0.14 respectively. The RR due to exposure to PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub> with the value of 1.0123, 1.028, 1.0029, and 1.0027 respectively. The results of this study indicated the necessity to keep the outdoor air quality in Makkah city specially during mass gatherings. It is worthy to study long term air pollution burden of disease over the two holy cities (Makkah and Madinah) in KSA using AirQ+ model.

**Keywords:** Air pollution, Hajj, Health Impact, Particulate Matter, relative risk.

## 1. Introduction

Hajj (pilgrimage) is most long-standing annual mass gathering event in Makkah city in the world. The holiest city in Islam with a population of near to 2 million, which gets doubles or even more during Hajj. It is an obligate ritual to every Muslim to undertake once in his lifetime. The whole period of stay for Hajj completion in KSA may take 60 days or more. Thus crowding, fatigue and the extreme climatic conditions such as heat and humidity and air pollution in the areas of Saudi Arabia are important factors for causing harmful health problems and mortality during the event [1,2,3]. Also, the changes in air quality in Makkah due to emissions from dust storms, increasing construction activities, large number of vehicles, petrochemical, and industrial activities may have significant impact on the health of pilgrims. Air pollution is a primary environmental issue of the urban region along with health problems and largest environmental health risk. Ambient air pollution is a complex mixture of pollutant. Particulate matter (PM), Ozone (O<sub>3</sub>), nitrogen dioxides (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), black carbon, carbon monoxide, heavy metals or black smoke are proxies for the air pollutant mixture. Worldwide, number of people who exposed to unhealthy air pollutants has significantly increased as a results of the rise in industrialization and urbanization [4]. It has been demonstrated that short-term exposure of air pollutants is associated with adverse health outcomes such as cardiovascular diseases (CVDs), stroke, diabetes, respiratory diseases, lung cancer, chronic obstructive pulmonary disease (COPD), and allergic illnesses as well as deaths [5,6,7,8,9]. The severity of these health risks depend on the ability of public health and safety systems to address or prepare for these changing threats, as well as factors such as an individual's behavior, age, gender, and economic status. Impacts vary based on a where a person lives, how sensitive they are to health threats, how much they are exposed to climate change impacts, and how well they and their community are able to adapt to change. Older adults are particularly sensitive to short-term particle exposure, with a higher risk of hospitalization and death [10]. Epidemiological and toxicological studies have been shown to be a strong indicator of risk associated with exposure to air pollutant from diverse sources in the different environment. For the implementation of more effective local, national, and global policies to reduce air pollution, quantitative estimation of health risk assessment now becomes a very important tool for policy makers and stakeholder. Therefore, it is important to choose the appropriate policy question, specific pollutants of the area and targeted population in air pollution risk

health assessment [11]. Several computer-based tools are available (AirQ+, AirCounts, Aphekon, EcoSense, etc.) that automate the process of an air pollution health risk assessment. AirQ+ is designed for the purposes for calculating estimates that may help to develop appropriate actions to protect public health [11]. This software is designed for health impact assessment of air pollution on human health over a certain time and place. The AirQ+ model calculations depend on procedures and concentration-based functions extracted from epidemiological studies [12]. AirQ+ estimates attributable proportion, attributable cases per 100,000 populations at risk, and proportion of cases in a range of air pollutants concentration (according to the baseline incidence of health outcomes, cut-off values of desired concentration, and relative risk (RR)). The present study aimed to evaluate the short-term impacts of PM10, PM2.5, NO2, and O3 pollutants on the pilgrims during 1437 H (2016) Hajj event.

## 2. Methodology

### 2.1. Makkah city:

Makkah is 70 km inland from Jeddah on the Red Sea, in a narrow valley 277 m above sea level at 21°23' north latitude and 39°51' east longitude with total area of 1,200 km<sup>2</sup>. The estimated population is more than 2 million. Pilgrims more than this number visit Makkah for the Hajj. The Great Mosque of Makkah, known as the Masjid al-Haram, is home to the Ka'bah, believed by Muslims to have been built by Abraham and Ishmael. It is one of Islam's holiest sites and the direction of prayer for all Muslims (qibla)[5].

### 2.2. Study data

The study used the data of population at risk, baseline incidence of health outcomes, and cut-off values of desired concentration for quantifying the short-term effects. The baseline incidence per 100,000 people was calculated based on the data from statistics of The Custodian of the Two Holy Mosques institute for Hajj and Umrah Research, Umm Al-Qura University, Makkah The respiratory diseases baseline incidence per 100,000 people was calculated based on the data such as the total number of mortality, death of people over 30 years old, and death caused by cardiovascular disease (CVD). The levels of PM10, PM2.5, O3, and NO2 which were used to evaluate the health effects on air pollution, were obtained during the period Hajj season from Mobile Lab. Station (AQMS-111) which was located in Almasfalah district, Makkah. The locations of the Makkah and sampling site are shown in Figure. 1.

### 2.3. Health impact assessment:

In this study, the software for health impact assessment of air quality (AirQ+) proposed by European Center for Environment and Health and World Health Organization (WHO) was used to quantify the effects of exposure to air pollution in pilgrims during Hajj (pilgrimage) event. Health effects considered in the current study were short-term mortality (due to all natural causes), non-specific mortality, mortality due to respiratory diseases, and mortality due to CVDc. Data entry and statistical analysis was done using SPSS 21.0 statistical software package.

## 3. Results and Discussion

The study used AirQ+1.3v to estimate the impact assessment of air pollution attributed to short-term exposure to PM10, PM2.5, O3, and NO2 in ambient air in the city of Makkah. During Hajj, the mortality attributable to short-term exposure were analyzed to estimate the effects of the changes in air pollution during the study period). Figure 2 shows the trends in concentrations of PM10, PM2.5, O3, and NO2 measured in Makkah during the period Hajj season (1437). Descriptive statistics of PM10, PM2.5, O3, and NO2 in Makkah are reported in table 1. The concentrations of PM2.5 during Hajj were

between 4.51 and 27.81  $\mu\text{g}/\text{m}^3$  with an average of 12.86  $\mu\text{g}/\text{m}^3$ . The concentrations of PM<sub>10</sub> during Hajj were between 69.22 and 237.67  $\mu\text{g}/\text{m}^3$  while the average was 118.90  $\mu\text{g}/\text{m}^3$ . The concentrations of O<sub>3</sub> were found between 8.58 and 23.75  $\mu\text{g}/\text{m}^3$  with an average of 14.86  $\mu\text{g}/\text{m}^3$ . The concentrations of NO<sub>2</sub> were found between 15.39 and 38.27 with an average of 24.71  $\mu\text{g}/\text{m}^3$ . Particulate matter is considered the most dangerous atmospheric pollutant in terms of its health effects. The daily average concentration was near to the guidelines in WHO (25  $\mu\text{g}/\text{m}^3$ ) [13]. In a similar study, it was reported that PM<sub>2.5</sub> levels was 13.2  $\mu\text{g}/\text{m}^3$ , during Hajj days in Makkah [14]. High levels of particulate matter in Makkah, especially during the Hajj period have been previously reported by several authors [15,16]. The main sources of PM<sub>2.5</sub> in western region of KSA may be due to heavy oil combustion, resuspended soil, industrial sources, traffic sources, and marine aerosols [17]. The highest detected PM<sub>10</sub> concentration was a value of 237.67  $\mu\text{g}/\text{m}^3$ . The results reveal that the daily average of PM<sub>10</sub> in Makkah city was similar to the guideline values of air quality guideline (50  $\mu\text{g}/\text{m}^3$ ) [12]. During Hajj event, the daily average NO<sub>2</sub> concentrations was 24.71  $\mu\text{g}/\text{m}^3$  which is lower than the WHO guideline (40  $\mu\text{g}/\text{m}^3$ ) [12]. For O<sub>3</sub>, the maximum concentration was 23.75  $\mu\text{g}/\text{m}^3$ , which is also lower than the guideline value of WHO (100  $\mu\text{g}/\text{m}^3$ ) [12]. The data of PM<sub>10</sub>, PM<sub>2.5</sub>, O<sub>3</sub>, and NO<sub>2</sub> concentrations were used to estimate the short-term effects (Table 2). The impacts of PM<sub>10</sub> and PM<sub>2.5</sub> changes may threaten health by affecting air in both indoors and outdoors. PM, when breathed in, can cause several health problems including asthma, rhinosinusitis, chronic obstructive pulmonary diseases and respiratory tract infections [18,19]. These impacts were estimated as the increase in cases and mortality for short-term exposure. The numbers of excess cases over total mortality were based on the (Relative Risk) RR values. RR is a ratio of the probability of an event occurring in the exposed group versus the probability of the event occurring in the non-exposed group. In this study, PM<sub>10</sub> the lowest health impact on the 1862909 pilgrims of Makkah city, causing no mortality (zero people during event). Recently, the AirQ software has been used by Fattore et al., 2011 who estimated the health impact in relation due to air pollutants in Northern Italy, where they found that PM<sub>10</sub> had caused an excess of total mortality of 4.4 out of 177 in a year [20], while Naddaf et al in Iran suggested PM<sub>10</sub> causing an excess of total mortality of 2,194 out of 47, 284 people in a year [21]. These and other results are higher than what we reported for PM<sub>10</sub> in this study. According to the estimates of AirQ+ model in table 2, the highest attributable proportion percentage was related to mortality, all-cause (age $\geq$ 30) caused by exposure to NO<sub>2</sub> with the value of 0.4. The present study showed that the effect of O<sub>3</sub> and NO<sub>2</sub> on total mortality was an excess of about 0, and 3 cases. Only 3 cases of mortality for pilgrims could be caused by short-term exposure to the concentration of NO<sub>2</sub> is 24.71  $\mu\text{g}/\text{m}^3$ . According to the estimates of AirQ+ model in Table 2, the highest number of attributable cases per 100,000 populations was caused by exposure to PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub> with the value of 0, 0, 0.01, and 0.14 respectively. The RR due to exposure to PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub> with the value of 1.0123, 1.028, 1.0029, and 1.0027 respectively. The attributable proportion of total mortality of pilgrims associated with PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub> was 0.0 % of total cases of this outcome. The world average number of deaths from household air pollution was reported as 53 per 100,000 people [22]. AirQ software has been widely used to assess short-term health impact due to air pollution. One study indicated that short-term exposure to an increase in PM<sub>2.5</sub> caused a 14% increase in mortality [23]. According to the WHO in 2014, each year, approximately 389,000 people in the world died due to the diseases caused by exposure to ambient air pollution. For example, the human health hazards related to air quality of two cities was estimated contaminated area in Italy [24]. Another study estimated human health hazards related to air quality and found that PM<sub>2.5</sub> had health impacts on population Italian cities with 8 additional cases from total of 177 deaths over a year [25]. Another study found that PM<sub>10</sub> caused 4



additional cases, and NO<sub>2</sub> and O<sub>3</sub> caused 3 additional cases from the total cases of mortality [20]. The lower number of health outcomes attributed to the studied pollutants in Makkah compared to the other similar studies could be due to the shorter period that spent by pilgrims during their rituals and as a result the differences in baseline mortalities. The study was limited by that the health impact focuses on individual air pollutants to exposure to several compounds, the study assumes that concentrations measured in fixed sampling point are representative of the average exposure suffered by people living in Makkah city.

This study illustrates a study case using the WHO approach to assess the impact of atmospheric pollution on human health during Hajj event. The AirQ software and the approach proposed by the WHO provide quantitative data on the impact of PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub> and O<sub>3</sub> on the health of temporary mass gatherings. In spite of some limitations, the results of this study are generally consistent with those of other health impact studies that used AirQ software. Therefore, the results of this study are comparable to other city studies. Even though the magnitude of the health impact estimated Hajj event is lower than other areas the world, the impact of air pollution on human health for pilgrims reveals considerable amount in this study there still remains the need for action to reduce the health burden of air pollution. The present study concluded that the average concentrations of PM<sub>10</sub>, PM<sub>2.5</sub>, O<sub>3</sub>, and NO<sub>2</sub> during Hajj were 12.86, 118.8917, 14.86, and 24.71 µg/m<sup>3</sup> respectively. The results showed low mortality due to the low air pollutants concentration and the short period of Hajj event. The results of this study indicated the necessity to improve the outdoor air quality in KSA.

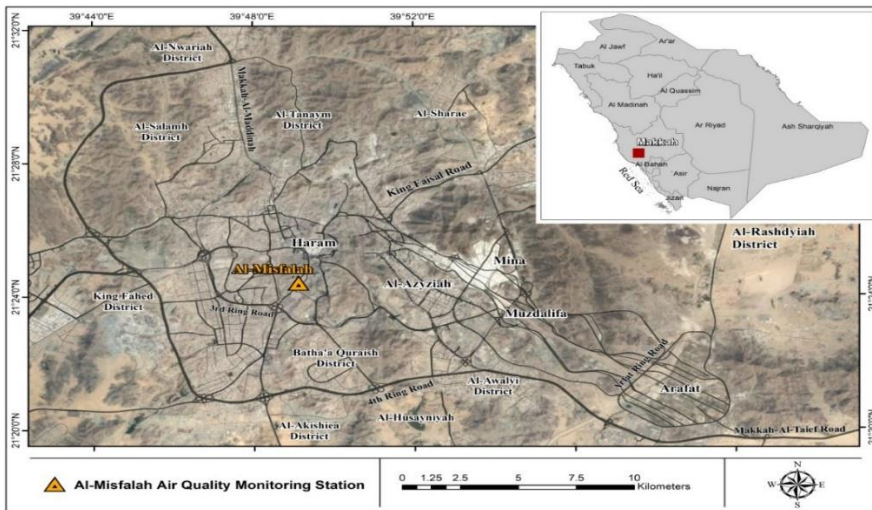
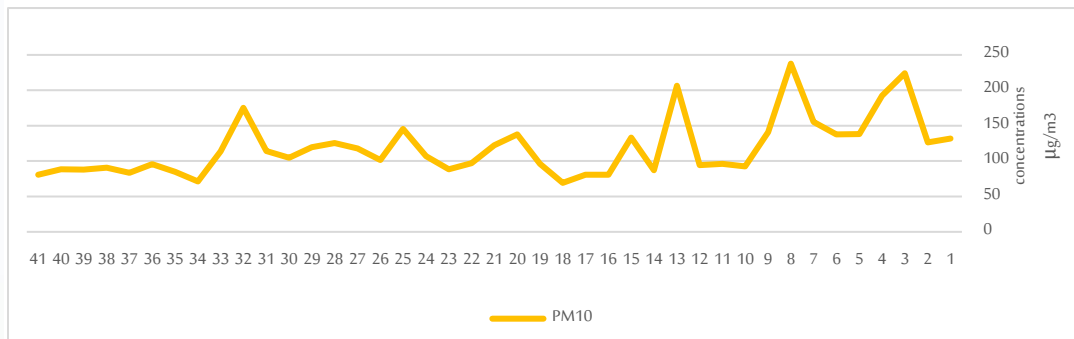


Fig. 1. Map of Makkah city showing sampling position.



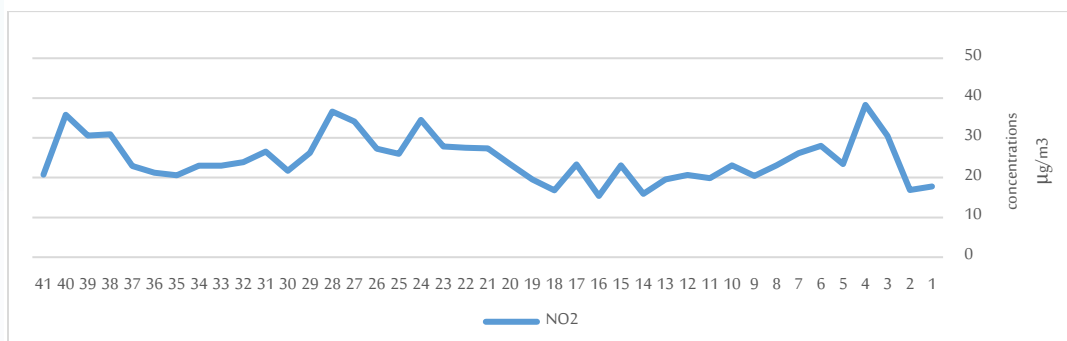
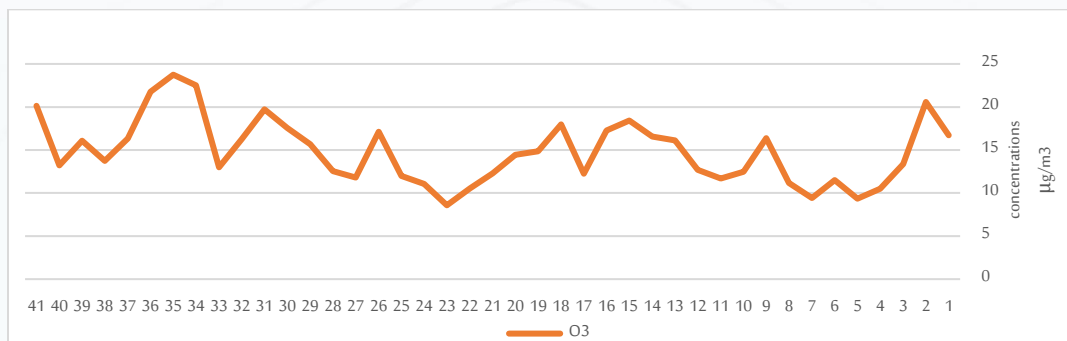
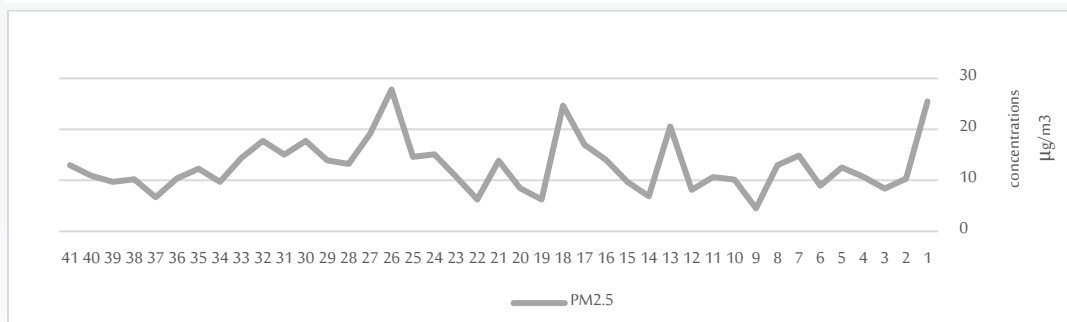


Figure 2. Trends in concentrations of PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub> (µg/m<sup>3</sup>) measured in Makkah (18 Aug-27Sep 2016).

Table 1. Descriptive statistics of ambient PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub> concentrations in Makkah

N	PM <sub>2.5</sub>	PM <sub>10</sub>	O <sub>3</sub>	NO <sub>2</sub>
Mean	12.8598	118.8917	14.86	24.71
Minimum	4.51	69.22	8.58	15.39
Maximum	27.81	237.67	23.75	38.27
Std. Deviation	5.22226	40.5256	3.7753	5.7347
Incidents (per 100 000)	18.68	34.52	34.52	34.52
Total population before event	1,578,722			
Total population after event	3441631			
Total no of death during event	643			
pilgrims at risk	1862909			
Year	2016			
Area Size (Km <sup>2</sup> )	1200			

Table 2. Short-term effects of death outcomes due to PM2.5, PM10, NO2 and O3 exposure among pilgrims in 2016.

Health endpoint	Pollutant	Attributable proportion (%)	Number of attributable cases	Number of attributable cases per 100,000 population	Relative risk
Mortality	PM <sub>2.5</sub>	0 (0.0-0.0)	0 (0-0)	0 (0.0-0.00)	1.0123 (1.0045-1.0201)
	PM <sub>10</sub>	0 (0.0-0.0)	0 (0-0)	0 (0.0-0.00)	1.028 (1.006-1.051)
	NO <sub>2</sub>	0.4 (0.23-0.56)	3 (2-4)	0.14 (0.08-0.19)	1.0027 (1.0016-1.0038)
	O <sub>3</sub>	0.03 (0.01-0.04)	0 (0-0)	0.01 (0.0-0.01)	1.0029 (1.0014-1.0043)

#### 4. Conclusions

The present study concluded that the average concentrations of PM10, PM2.5, O3, and NO2 during Hajj were 12.86, 118.8917, 14.86, and 24.71 µg/m3 respectively. The highest impacts estimated in hajj event was related to mortality attributable to NO2 with was almost 3 cases from the total cases. The attributable proportion of total mortality of pilgrims associated with all of PM2.5, PM10, O3 was 0.0 % of total cases. The highest number of attributable cases per 100,000 populations was caused by exposure to PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub> with the value of 0, 0, 0.01, and 0.14 respectively. The RR due to exposure to PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub> with the value of 1.0123, 1.028, 1.0029, and 1.0027 respectively. The results indicated low mortality due to the air pollutants concentration and the short period of Hajj event.

#### 5. Recommendations

The results of this study indicated the necessity to improve the outdoor air quality in Makkah city specially during mass gatherings. It is worthy to study long term air pollution burden of disease over the two holy cities (Makkah and Madinah) in KSA using AirQ+ model.

#### References

- 1- Madani TA, TM Ghabrah, MA Al-Hedaithy, MA Alhazmi, TA Alazraqi, AM Albarrak, 2006: Causes of hospitalization of pilgrims in the Hajj season of the Islamic year 1423 (2003). *Ann Saudi Med.* 26:346-51.
- 2- Al-Ghamdi SM, HO Akbar, YA Qari, OA Fathaldin, RS Al-Rashed, 2003. Pattern of admission to hospitals during muslim pilgrimage (Hajj). *Saudi Med J.* 24:1073-6.
- 3- Balkhy HH, ZA Memish, S Bafaqeer, MA Almuneef, 2004: Inß uenza a common viral infection among Hajj pilgrims: Time for routine surveillance and vaccination. *J Travel Med.* 11:82-6.
- 4- WHO. Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide, and Sulfur Dioxide. WHO, Geneva (2006)
- 5- Jing Li, Alistair Woodward, Xiang-Yu Hou, Tong Zhu, Jinliang Zhang, Helen Brown, Jun Yang, Rennie Qin, Jinghong Gao, Shaohua Gu, Jing Li, Lei Xu, Xiaobo Liu, Qiyong Liu, Modification of the effects of air pollutants on mortality by temperature: A systematic review and meta-analysis. *Science of The Total Environment*, 2017, Volume 575, Pages 1556-1570.
- 6- Y. Cai, B. Zhang, W. Ke, B. Feng, H. Lin, J. Xiao, et al. Associations of short-term and long-term exposure to ambient air pollutants with hypertension: a systematic review and meta-analysis *Hypertension*, 68 (2016), pp. 62-70
- 7- A. Zanobetti, F. Dominici, Y. Wang, J.D. Schwartz. A national case-crossover analysis of the short-term effect of PM2.5 on hospitalizations and mortality in subjects with diabetes and neurological disorders *Environ. Health*, 13 (2014), p. 38.
- 8- W.S. Yang, X. Wang, Q. Deng, W.Y. Fan, W.Y. Wang. An evidence-based appraisal of global association between air pollution and risk of stroke *Int. J. Cardiol.*, 175 (2014), pp. 307-313.
- 9- H. Li, R. Chen, X. Meng, Z. Zhao, J. Cai, C. Wang, et al. Short-term exposure to ambient air pollution and coronary heart disease mortality in 8 Chinese cities. *Int. J. Cardiol.*, 197 (2015), pp. 265-270

- 10- Sarofim, Marcus C, 2016: The impacts of climate change on human health in the united states a Scientific Assessment 2 Temperature-related death and illness. Lead.
- 11- Kumar A and R K Mishra, 2017: Air Pollution Health Risk Based on AirQ+ Software Tool. IJART. 2 (3): 190-199.
- 12- WHO, (2017), Evolution of WHO air quality guidelines: past, present and future, WHO Regional Office for Europe, Copenhagen, On line at: [https://www.euro.who.int/\\_\\_data/assets/pdf\\_file/0019/331660/Evolution-air-quality.pdf](https://www.euro.who.int/__data/assets/pdf_file/0019/331660/Evolution-air-quality.pdf).
- 13- WHO, 2006: Air quality guidelines: global update 2005: particulate matter, ozone, nitrogen dioxide, and sulfur dioxide. World Health Organization.
- 14- Munir S, T M Habeebullah, A F Mohammed, E A Morsy, M Rehan, K Ali, 2017: Analysing PM2.5 and its Association with PM10 and Meteorology in the Arid Climate of Makkah, Saudi Arabia. Aerosol and Air Quality Research. 17: 453–464.
- 15- Habeebullah T M, 2013. An Analysis of Air Pollution in Makkah - a View Point of Source Identification. EnvironmentAsia. 6 (2): 11-17
- 16- Khwaja, H A, O SAburizaiza, A Siddique, M M Hussain, F Khatib, J Zeb; DR Blake, 2014: An assessment of air quality in the surrounding holy places of Mecca, Saudi Arabia during Hajj. Trends in Green chem. 3:2 DOI: 10.21767/2471-9889-C1-002.
- 17- Khodeir, M., Shamy, M., Alghamdi, M., Zhong, M., Sun, H., Costa, M., Chen, L.C. and Maciejczyk, P.M. Source apportionment and elemental composition of PM2.5 and PM10 in Jeddah City, Saudi Arabia. Atmos. Pollut. Res. 2012; 3: 331–340.
- 18- WHO, 2003: Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide. Report on a WHO Working Group Bonn, Germany 13–15 January 2003.
- 19- Munir S, S Gabr, T M Habeebullah, M A Janajrah, 2016. Spatiotemporal analysis of fine particulate matter (PM2.5) in Saudi Arabia using remote sensing data. The Egyptian Journal of Remote Sensing and Space Sciences. 19: 195–205.
- 20- Fattore, E., Paiano, V., Borgini, A., Tittarelli, A., Bertoldi, M., Crosignani, P., Fanelli, R. (2011) Human health risk in relation to air quality in two municipalities in an industrialized area of northern Italy. Environmental Research 111(8), 1321-1327.
- 21- Naddafi, K., Hassanvand, M.S., Yunesian, M., Momeniha, F., Nabizadeh, R., Faridi, S., Gholampour, A. (2012) Health impact assessment of air pollution in megacity of Tehran, Iran. Iranian Journal of Environmental Health Sciences & Engineering 9, 1-7.
- 22- WHO, 2014: Burden of disease from household air pollution for 2012. World Health Organization.
- 23- Neuberger M, Moshammer H, Rabczenko D, 2013: Acute and subacute effects of urban air pollution on cardiopulmonary emergencies and mortality: time series studies in Austrian cities. Int J Environ Res Public Health. 10:4728–4751.
- 24- Jeong S.J., (2013), The impact of air pollution on human health in Suwon City, Asian Journal of Atmospheric Environment, 7, 227-233.
- 25- Malakootian, M., & Mohammadi, A. (2020). Estimating health impact of exposure to pm2.5, no2 and o3 using airq+ model in kerman, iran . Environmental Engineering and Management Journal, 19(8), 1317-1323.

