



# Innovative Technologies in Preventing and Managing Heat Exhaustion During Large Religious Gatherings

Ameneh Marzban <sup>1, \*</sup>

<sup>1</sup> Department of Health in Disasters and Emergencies, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran

\*Corresponding Author: Department of Health in Disasters and Emergencies, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran. Email: [amenemarzban@yahoo.com](mailto:amenemarzban@yahoo.com)

Received: 18 April, 2025; Revised: 25 April, 2025; Accepted: 25 April, 2025

## Abstract

**Context:** The Arbaeen pilgrimage, one of the largest annual religious gatherings, attracts millions of participants to Karbala, Iraq, presenting significant spiritual and logistical challenges. However, the extreme heat and overcrowded conditions during the pilgrimage pose serious health risks, particularly heat exhaustion, which can lead to severe complications if unmanaged. Innovative technologies have emerged as key solutions to address these challenges and enhance health management.

**Objectives:** This narrative review aims to examine the environmental and social factors contributing to heat exhaustion during large religious gatherings and explore the role of emerging technologies in preventing and managing heat stress.

**Evidence Acquisition:** A qualitative approach was employed, synthesizing data from academic studies, field reports, and expert opinions. Literature searches were conducted using databases such as PubMed and Google Scholar, focusing on keywords including "heat exhaustion", "wearable devices", "hydration technologies", and "crowd management". Thematic analysis categorized findings into environmental risks, technological interventions, and implementation challenges.

**Results:** Key findings revealed major contributors to heat exhaustion, including high ambient temperatures, crowding, and limited hydration access. Technologies such as wearable monitoring devices, portable cooling units, smart hydration systems, mobile health applications, and AI-driven crowd management tools were identified as effective in mitigating heat stress risks. However, challenges in accessibility, affordability, cultural sensitivity, and infrastructure deployment were noted.

**Conclusions:** Technological innovations hold immense potential in preventing heat exhaustion during mass gatherings like the Arbaeen pilgrimage. Effective implementation requires stakeholder collaboration, proactive planning, and educational campaigns to maximize impact. This review highlights the need for integrating research, funding, and community-driven efforts to ensure the safety and well-being of pilgrims.

**Keywords:** Heat Exhaustion, Pilgrimage, Innovative Technologies, Hydration, Cooling Systems

## 1. Context

The Arbaeen pilgrimage, recognized as one of the largest annual religious gatherings, attracts millions of participants who journey to Karbala, Iraq, for spiritual reflection and commemoration (1, 2). While this pilgrimage is a profound testament to faith and devotion, it presents unique challenges due to harsh environmental conditions, overcrowding, and prolonged physical exertion (3). Among the most pressing health concerns, heat exhaustion remains a critical issue, exacerbated by extreme temperatures,

inadequate hydration, and restricted airflow in densely populated areas (4). Without proper intervention, heat exhaustion can escalate to life-threatening conditions such as heatstroke, making proactive health management essential (5).

Traditional health interventions, while helpful, are often insufficient in managing the scale and severity of heat-related illnesses in such mass gatherings (2). Therefore, technological innovations have emerged as essential tools in mitigating heat stress, offering solutions such as wearable monitoring devices, portable cooling units, smart hydration systems, mobile health

applications, and AI-driven crowd management tools (6). These technologies can transform how heat exhaustion is prevented and managed, ensuring greater safety and well-being for pilgrims (7).

This narrative review explores the environmental and social factors contributing to heat exhaustion during the Arbaeen pilgrimage and examines how innovative technologies can address these challenges. By analyzing existing research and implementation strategies, this review aims to provide actionable insights for policymakers, healthcare professionals, and event organizers, paving the way for smarter and more efficient heat stress management during large-scale religious gatherings.

## 2. Evidence Acquisition

Regarding this review, credible databases, including PubMed, Scopus, Embase, Science Direct, Google Scholar, Magiran, and the Scientific Information Database (SID), were searched using keywords such as "Heat exhaustion in mass gatherings", "Pilgrimage health risks and interventions", "Wearable devices for heat stress management", "Smart hydration technologies", and "AI-driven crowd monitoring" from the published literature in both English and Persian languages. A variety of studies, including prospective cohort, retrospective, case-control, clinical guidelines, cross-sectional, and review articles up to 2025, were examined (1).

It is recommended to provide a table summarizing innovative technologies under the title "Innovative Technologies in Preventing and Managing Heat Exhaustion during Large Religious Gatherings." This table should include details such as the type of technology, its application, benefits, and any implementation challenges identified in the literature. This structured summary will offer a clear overview of the technological solutions available for managing heat stress in large gatherings (Table 1).

## 3. Results

The findings of this narrative review reveal a multifaceted approach to addressing heat exhaustion during large religious gatherings such as the Arbaeen pilgrimage. The insights underscore both the challenges posed by environmental and social factors and the solutions offered through innovative technologies. The results are categorized into three main areas: Challenges of heat exhaustion, technological solutions for heat stress management, and implementation challenges and considerations. These findings provide a foundation for understanding how effective

interventions can significantly enhance the safety and well-being of pilgrims.

### 3.1. Heat Stress Challenges

The environmental and social conditions faced by pilgrims during large gatherings are substantial contributors to heat exhaustion (8). Key challenges identified include.

#### 3.1.1. High Ambient Temperatures

Pilgrims often face extreme heat, with temperatures exceeding 40°C. Prolonged exposure to such conditions places significant strain on thermoregulatory mechanisms, leading to dehydration, fatigue, and, ultimately, heat exhaustion if left unaddressed (9, 10).

#### 3.1.2. Crowding and Restricted Airflow

The density of large crowds in pilgrimage routes reduces ventilation and exacerbates heat stress (3). Overcrowded pathways amplify exposure to ambient heat and restrict the mobility of individuals seeking relief or hydration, particularly during peak hours (11).

#### 3.1.3. Hydration and Nutrition Challenges

Many pilgrims neglect fluid intake or fail to consume electrolyte-rich beverages, leading to dehydration and electrolyte imbalance (12). This is compounded by reliance on processed or high-sodium foods, which increase the risk of heat-related illnesses (13).

#### 3.1.4. Cultural and Traditional Attire

Many pilgrims wear traditional clothing that, while culturally significant, limits airflow and increases body heat retention (1). This adds to the physiological burden in environments of high heat and humidity (5, 14).

The cumulative effect of these factors creates a high-risk environment, particularly for vulnerable groups such as the elderly, children, and those with pre-existing health conditions (15).

### 3.2. Technological Solutions for Heat Stress Management

Emerging technologies offer promising solutions to combat the challenges of heat exhaustion (4, 16). The review highlights several innovative approaches.

#### 3.2.1. Wearable Monitoring Devices

Wearable devices equipped with sensors provide real-time monitoring of vital signs, including core body temperature, heart rate, and hydration levels. These

**Table 1.** Preventing and Managing Heat Exhaustion during Large Religious Gatherings

Technology Type	Application	Benefits
<b>Wearable monitoring devices</b>	Real-time tracking of vital signs such as body temperature and heart rate	Early warning system to prevent heat exhaustion
<b>Portable cooling units</b>	Misting stations and mobile cooling fans	Reduces ambient temperature in crowded and poorly ventilated areas
<b>Cooling apparel</b>	Self-cooling vests and thermal blankets	Helps regulate body temperature and reduce heat stress
<b>Smart hydration systems</b>	Automated water stations providing electrolyte-rich beverages	Continuous access to clean water and reminders for hydration
<b>Mobile health applications</b>	Guides pilgrims to cooling zones and sends personalized alerts	Improves rest and hydration management based on environmental and individual factors
<b>AI-Powered crowd density monitoring</b>	Uses drones and sensors to analyze crowd movement patterns	Reduces overcrowding and directs pilgrims to less congested areas

devices alert users and healthcare personnel to early signs of heat stress, enabling timely intervention (17). Vulnerable groups, such as individuals with chronic illnesses or advanced age, can benefit significantly from these devices, reducing the risk of severe complications (18).

### 3.2.2. Portable Cooling Units

Misting fans and mobile cooling stations are practical interventions for reducing ambient temperatures in high-density areas (19). These units operate efficiently even in environments with limited infrastructure (20). Wearable cooling gear, such as self-cooling vests or thermal blankets, offers personalized cooling solutions, particularly for those undertaking long walking distances in intense heat (11, 16).

### 3.2.3. Smart Hydration Systems

Automated hydration stations and smart water dispensers provide easy access to clean drinking water and encourage regular fluid consumption (5). These systems can also dispense electrolyte-enriched beverages to help maintain optimal hydration and electrolyte balance (2). Integration of consumption-tracking sensors ensures individuals are reminded to hydrate, mitigating the risks associated with dehydration (10).

### 3.2.4. Mobile Health Applications

These applications offer real-time guidance, directing pilgrims to the nearest cooling zones, medical facilities, or hydration points (21). They also provide educational content on recognizing symptoms of heat exhaustion and offer tailored alerts reminding participants to rest or hydrate based on environmental and individual data inputs (3, 7).

### 3.2.5. Crowd Density Monitoring and Management

AI-driven surveillance systems and drones analyze crowd movement patterns, identifying areas of high density where heat stress is likely to be aggravated (6, 11). Real-time data from these technologies allows event organizers to optimize crowd flow, redistribute pilgrims to less congested areas, and strategically deploy resources such as hydration stations or medical units (5, 7, 19). Each of these technological solutions addresses a specific aspect of heat exhaustion, working together to create a safer environment for pilgrims (2).

## 3.3. Implementation Challenges and Considerations

Although the reviewed technologies show significant potential, their widespread adoption and effective implementation face several challenges.

### 3.3.1. Accessibility and Affordability

The cost of advanced technologies, such as wearable monitors or smart hydration systems, may limit their accessibility to all participants (17). Efforts must focus on making these solutions affordable and scalable (1).

### 3.3.2. Cultural Sensitivity

Interventions must respect the cultural and spiritual practices of pilgrims. For example, wearable devices or cooling gear should align with traditional attire and religious customs to encourage acceptance (18, 21).

### 3.3.3. Infrastructure and Logistics

Effective deployment of hydration stations, cooling units, and crowd monitoring systems requires robust infrastructure and planning (15). Limited resources and logistical hurdles in pilgrimage routes can complicate implementation (14, 16, 18).

### 3.3.4. Awareness and Education

Many pilgrims lack awareness about the importance of hydration, heat exhaustion symptoms, or available technological solutions (5). Educational campaigns must accompany technological interventions to maximize their impact (2, 11, 21).

Despite these challenges, proactive planning, stakeholder collaboration, and pilot programs during smaller-scale gatherings can pave the way for successful integration of these technologies (13, 21).

## 4. Conclusions

The findings of this review not only highlight the critical need for innovative solutions to address heat exhaustion but also emphasize the importance of strategic planning and collaboration in their implementation. Together, these results provide a roadmap for enhancing the safety and comfort of pilgrims during large religious gatherings.

The prevention and management of heat exhaustion during such events demand proactive and innovative approaches. By leveraging wearable devices, portable cooling units, smart hydration systems, mobile health apps, and crowd monitoring technologies, stakeholders can significantly enhance the safety and comfort of pilgrims. These measures not only reduce the incidence of heat-related illnesses but also ensure that the pilgrimage remains a positive and fulfilling experience for all participants.

## Footnotes

**Authors' Contribution:** The author wrote the entire article.

**Conflict of Interests Statement:** The author have no conflict of interest.

**Data Availability:** The dataset presented in the study is available on request from the corresponding author during submission or after publication.

**Funding/Support:** This study was supported in part by author.

## References

1. Aleeban M, Mackey TK. Global Health and Visa Policy Reform to Address Dangers of Hajj during Summer Seasons. *Front Public Health*. 2016;4:280. [PubMed ID: 28066758]. [PubMed Central ID: PMC517761]. <https://doi.org/10.3389/fpubh.2016.00280>.
2. Hasan F, Marsia S, Patel K, Agrawal P, Razzak JA. Effective Community-Based Interventions for the Prevention and Management of Heat-Related Illnesses: A Scoping Review. *Int J Environ Res Public Health*. 2021;18(16). [PubMed ID: 34444112]. [PubMed Central ID: PMC8394078]. <https://doi.org/10.3390/ijerph18168362>.
3. Alkassas W, Rajab AM, Alrashood ST, Khan MA, Dibas M, Zaman M. Heat-related illnesses in a mass gathering event and the necessity for newer diagnostic criteria: a field study. *Environ Sci Pollut Res Int*. 2021;28(13):16682-9. [PubMed ID: 33389467]. [PubMed Central ID: PMC7778691]. <https://doi.org/10.1007/s11356-020-12154-4>.
4. Yezli S, Ehaideb S, Yassin Y, Alotaibi B, Bouchama A. Escalating climate-related health risks for Hajj pilgrims to Mecca. *J Travel Med*. 2024;31(4). [PubMed ID: 38457640]. [PubMed Central ID: PMC1149718]. <https://doi.org/10.1093/jtm/taae042>.
5. Almuzaini Y, Alburayh M, Alahmari A, Alamri F, Sabbagh AY, Alsalamah M, et al. Mitigation strategies for heat-related illness during mass gatherings: Hajj experience. *Front Public Health*. 2022;10:957576. [PubMed ID: 36062122]. [PubMed Central ID: PMC9433897]. <https://doi.org/10.3389/fpubh.2022.957576>.
6. McCloskey B, Memish ZA, Sharma A, Traore T, Parker S, Zumla A. Confronting heat-related illnesses and deaths at mass gathering religious and sporting events. *Lancet Planet Health*. 2024;8(8):e522-3. [PubMed ID: 39009004]. [https://doi.org/10.1016/S2542-5196\(24\)00161-X](https://doi.org/10.1016/S2542-5196(24)00161-X).
7. Yezli S. Risk factors for heat-related illnesses during the Hajj mass gathering: an expert review. *Rev Environ Health*. 2023;38(1):33-43. [PubMed ID: 34714988]. <https://doi.org/10.1515/reveh-2021-0097>.
8. Qari S. The Hajj: Hazards of Heat Exposure and Prevalence of Heat Illnesses among Pilgrims. *J Liaquat Univ Med Health Sci*. 2019;18(4):252-7. <https://doi.org/10.22442/jlumhs.191840637>.
9. 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). [PubMed ID: 31518432]. <https://doi.org/10.1093/jtm/taz069>.
10. Al Mayahi ZK, Ali Kabbash I. Perceptions of, and Practices for Coping with, Heat Exposure among Male Arab Pilgrims to the Hajj, 1436. *Prehosp Disaster Med*. 2019;34(2):161-74. [PubMed ID: 30968815]. <https://doi.org/10.1017/S1049023X19000025>.
11. Memish ZA, Zumla A, Parker S. Heat-related deaths during the 2024 Hajj pilgrimage. *J Travel Med*. 2024;31(6). [PubMed ID: 38995914]. <https://doi.org/10.1093/jtm/taae096>.
12. Danish Khan I, Hussaini SB, Khan S, Ahmad FM, Faisal FA, Salim MA, et al. Emergency Response of Indian Hajj Medical Mission to Heat Illness Among Indian Pilgrims in Tent-Clinics at Mina and Arafat During Hajj, 2016. *Int J Travel Med Global Health*. 2017;5(4):135-9. <https://doi.org/10.1517/ijtmgh.2017.26>.
13. Almuzaini Y, Abdulmalek N, Ghallab S, Mushi A, Yassin Y, Yezli S, et al. Adherence of Healthcare Workers to Saudi Management Guidelines of Heat-Related Illnesses during Hajj Pilgrimage. *Int J Environ Res Public Health*. 2021;18(3). [PubMed ID: 33525576]. [PubMed Central ID: PMC7908601]. <https://doi.org/10.3390/ijerph18031156>.
14. Saeed F, Schleussner C, Almazroui M. From Paris to Makkah: heat stress risks for Muslim pilgrims at 1.5 °C and 2 °C. *Environ Res Letters*. 2021;16(2). <https://doi.org/10.1088/1748-9326/abd067>.
15. Abdelmoety DA, El-Bakri NK, Almowallid 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. [PubMed ID: 29662887]. [PubMed Central ID: PMC5832155]. <https://doi.org/10.1155/2018/5629474>.
16. Olsen D. Disease- and health-related issues at mass religious gatherings. In: Shinde KA, editor. *Religious tourism and the environment*. Wallingford, United Kingdom: CABI; 2020.

17. Dasari HP, Desamsetti S, Langodan S, Viswanadhapalli Y, Hoteit I. Analysis of Outdoor Thermal Discomfort Over the Kingdom of Saudi Arabia. *Geohealth*. 2021;5(6). e2020GH000370. [PubMed ID: 34141978]. [PubMed Central ID: PMC8182280]. <https://doi.org/10.1029/2020GH000370>.
18. Matsee W, Charoensakulchai S, Khatib AN. Heat-related illnesses are an increasing threat for travellers to hot climate destinations. *J Travel Med*. 2023;30(4). [PubMed ID: 37225235]. [PubMed Central ID: PMC10289510]. <https://doi.org/10.1093/jtm/taad072>.
19. Yezli S, Khan AH, Yassin YM, Khan AA, Alotaibi BM, Bouchama A. Association of Ambient Temperature with Mortality in Resident and Multiethnic Transient Populations in a Desert Climate, 2006-2014. *Environ Health Perspect*. 2023;131(4):47004. [PubMed ID: 37018010]. [PubMed Central ID: PMC10075304]. <https://doi.org/10.1289/EHP9838>.
20. Choi Y, Eltahir EA. Heat Stress During Arba'een Foot-Pilgrimage (World's Largest Gathering) Projected to Reach "Dangerous" Levels Due To Climate Change. *Geophysical Research Letters*. 2022;49(19). <https://doi.org/10.1029/2022gl099755>.
21. Kolivand P, Moslehi S, Marzban A, Bastami M, Sayadi H. Investigating the Risk Perception of Arbaeen Pilgrims Regarding Heat Stroke. *Trauma Monthly*. 2025;30(1):1346-52. <https://doi.org/10.30491/tm.2024.468507.1750>.