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Systematic Review

The Role of Hydration, Electrolyte Balance, and Diet in Preventing Heatstroke among Arbaeen Pilgrims: A Systematic Review

Mohammad Taghi Bastami[1], PirHossein Kolivand[2], Ameneh Marzban[1], Mostafa Modareszadeh[1], Shandiz Moslehi[3*]

[1] Department of Health in Disasters and Emergencies, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran

[2] Research Center for health Management Mass Gathernig Red Crescent Society of the Islamic Republic of Iran, Tehran, Iran.
[3] Health Management and Economics Research Center, Health Management Research Institute, Iran University of Medical Sciences, Tehran, Iran
***Corresponding Author**: Shandiz Moslehi, Health Management and Economics Research Center, Health Management Research Institute, Iran University of Medical Sciences, Tehran, Iran. Email: taghi.bastami@yahoo.com

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Abstract

Introduction: Arbaeen is one of the world's largest religious gatherings, during which millions of pilgrims walk long distances under extreme heat conditions, increasing the risk of heat-related illnesses such as heatstroke, dehydration, and exhaustion. Adequate hydration, electrolyte balance, and proper nutrition are therefore essential for maintaining physical performance and preventing health complications. This systematic review aimed to evaluate the role of hydration, electrolyte balance, and diet in preventing heatstroke among Arbaeen pilgrims.

Method: This systematic review searched PubMed, Web of Science, Scopus, Google Scholar, MagIran, and SID for relevant Persian and English studies published up to May 25, 2025. Official reports and documents from international organizations, including the WHO, CDC, FEMA, IFRC, UN, and FAO, were also reviewed. The review process followed PRISMA guidelines, and qualitative content analysis was used to synthesize the extracted data.

Result: A total of 9,913 records were identified, of which 10 studies met the inclusion criteria and were included in the final analysis. The findings were categorized into five main themes, 14 categories, and 28 subcategories. Major themes included factors contributing to heatstroke among pilgrims, the role of hydration and nutrition in thermoregulation, the importance of fluid and electrolyte intake during extreme heat exposure, the impact of diet on physical and mental performance, and strategies to improve hydration and dietary practices during the Arbaeen pilgrimage. Evidence indicated that adequate fluid intake, electrolyte replacement (particularly sodium and potassium), and balanced dietary patterns reduce dehydration, fatigue, and thermal stress while improving endurance and overall well-being.

Conclusion : Hydration, electrolyte balance, and proper nutrition play a critical role in preventing heatstroke among Arbaeen pilgrims. Culturally appropriate nutritional strategies and hydration practices can enhance pilgrims' safety and physical resilience during this demanding journey. Further field-based and longitudinal studies are recommended to develop evidence-based health guidelines for mass religious gatherings.

Keywords: Heatstroke, Hydration, Electrolyte Balance, Diet, Arbaeen.

Introduction

The Arbaeen pilgrimage stands as one of the world's most significant and largest annual religious gatherings, drawing millions of devotees from across the globe [1-4]. This profound spiritual journey often involves traversing hundreds of kilometers on foot, presenting a physically demanding endeavor [5,6]. Pilgrims are exposed to extreme environmental conditions, particularly intense heat, which poses substantial health risks [7]. A primary concern is heatstroke, a life-threatening condition arising from prolonged exposure to high temperatures, exacerbated by dehydration and strenuous physical activity [8-9].

Heatstroke occurs when the body's thermoregulatory mechanisms are overwhelmed, leading to a dangerous increase in core body temperature [10,11]. Symptoms can range from mild dizziness and fatigue to severe confusion, organ damage, and loss of consciousness, underscoring the critical need to understand its contributing factors [12]. Dehydration and electrolyte imbalances are central to the development of heatstroke, significantly impacting muscle function, cognitive processes, and cardiovascular stability [4]. Given the arduous nature of the pilgrimage, pilgrims require effective hydration strategies and dietary interventions to sustain energy, enhance endurance, and, crucially, prevent heat-related illnesses [13].

The health and economic burdens associated with heatstroke among Arbaeen pilgrims are considerable, stemming from the extreme environmental conditions and the sheer scale of the gathering [14]. Treating severe dehydration, electrolyte disturbances, and heat-related illnesses places immense strain on healthcare facilities and emergency services, often leading to overcrowded medical centers and shortages of supplies [7,15]. Beyond immediate medical costs, there are economic impacts related to lost productivity and the financial outlay for organizers to provide essential preventive measures such as hydration stations and cooling zones [16]. Implementing targeted hydration and dietary strategies can substantially mitigate these burdens, fostering a safer and more sustainable pilgrimage experience.[15]

Effective thermoregulation, which refers to the body's capacity to maintain a stable internal temperature, is fundamentally dependent on proper hydration and electrolyte balance [17,18]. Paramount to mitigating the risk of heatstroke are adequate fluid intake, judicious electrolyte consumption (with particular emphasis on sodium and potassium), and a diet fortified with essential nutrients [19]. Hydration plays a critical role in supporting circulatory function and facilitating the body's innate cooling processes [7]. The consumption of water-dense foods, coupled with the assurance of sufficient key electrolyte intake, serves to prevent excessive fluid depletion and sustain optimal cellular functions [16,20]. Notwithstanding the well-established significance of these elements, a dearth of systematic investigation persists regarding the exact interplay of hydration, electrolyte balance, dietary intake, and heatstroke prevention, particularly as it pertains to the unique context of the Arbaeen pilgrim population, thus constituting a notable knowledge gap [21].

This systematic review endeavors to address this gap by synthesizing the existing literature on the impact of hydration strategies, electrolyte balance, and dietary choices in preventing heatstroke among Arbaeen pilgrims. By critically analyzing current research, this review aims to provide evidence-based recommendations that can enhance pilgrims' health, improve their endurance, and ultimately ensure a safer spiritual journey.

Methods

Study Design and Registration

This systematic review was conducted in accordance with the PRISMA guidelines to ensure transparency and methodological rigor in study identification, screening, selection, and reporting [22]. The review protocol was registered in advance on PROSPERO on May 25, 2025 (Registration ID: CRD420251057702).

Literature Search

A comprehensive search strategy was designed to identify studies examining the role of hydration, electrolyte balance, and diet in preventing heatstroke among Arbaeen pilgrims. The search terms were developed based on the review question and included controlled vocabulary and free-text keywords related to heatstroke, heat stress, hydration, fluid intake, electrolyte balance, diet, nutrition, nutritional status, Arbaeen, and mass gatherings. Synonyms and related terms were identified using the Medical Subject Headings (MeSH) database and by reviewing terminology used in relevant previous studies.

The search was conducted in the following databases and academic search engines: PubMed, Web of Science, Scopus, Google Scholar, Magiran, and SID. We searched for studies published in Persian or English up to May 25, 2025. In addition, to capture potentially relevant evidence not indexed in academic databases, we reviewed authoritative institutional sources, including the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), FEMA, the International Federation of Red Cross and Red Crescent Societies (IFRC), the United Nations (UN), and the Food and Agriculture Organization (FAO).

To identify relevant studies, a set of core search terms was developed, including: heat, heat stroke, nutritional status, nutrition therapy, Arbaeen, and mass gatherings. Synonyms and related terms were refined using the MeSH database and cross-referenced with terminology found in previous literature. A structured search strategy was applied across major databases and academic search engines, including PubMed, Web of Science, Scopus, Google Scholar, Magiran, and SID, targeting Persian and English language publications available up to May 25, 2025. Additionally, we reviewed content from authoritative institutional websites such as WHO, CDC, FEMA, IFRC, UN, and FAO to supplement the academic findings. The detailed search strategy used for PubMed, WOS, and Scopus is presented in Table 1.

Inclusion and exclusion criteria

We included studies published in English or Persian that investigated the role of hydration, electrolyte balance, and/or diet in the prevention of heatstroke among Arbaeen pilgrims or in closely related mass-gathering or hot-environment settings relevant to the review question. Studies with various research designs were considered eligible if they addressed one or more of the key exposure domains of this review. Searches were conducted from database inception to May 25, 2025.

We excluded studies for which the full text was unavailable, studies published in languages other than English or Persian, studies not relevant to the relationship between hydration, electrolyte balance, diet, and heatstroke prevention, and review articles.

Study selection

After the initial database search, duplicate records were removed using EndNote software (version X8). Two independent reviewers screened the titles and abstracts of the remaining records to identify potentially relevant studies. Articles deemed eligible were then retrieved in full text and assessed for final inclusion.

Any disagreements between the two reviewers were resolved through discussion, and if consensus could not be reached, a third reviewer was consulted. In addition, studies identified through manual searching were screened and considered during the final selection process. The study selection process is presented in Figure 1.

Data extraction

A standardized data extraction form was used to collect relevant information from the included studies. The extracted items included author name, year of publication, country or setting, study design, objectives, participant characteristics, and key findings related to hydration, electrolyte balance, and diet in heatstroke prevention.

Two reviewers independently extracted the data. In cases of disagreement, a third reviewer examined the disputed information and helped resolve inconsistencies. The extracted data were summarized and presented in Table 2.

Data analysis

Thematic analysis was applied to interpret the qualitative data, following the methodological framework proposed by Braun and Clarke. This approach enabled systematic identification and exploration of recurring patterns across the studies. The analysis was conducted in six stages: (1) becoming familiar with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the final report (23). Coding was performed iteratively, with repeated readings to refine subcategories. These subcategories were then grouped into broader categories, which ultimately led to the emergence of five central themes. The entire process was facilitated using MaxQDA10 software.

Quality appraisal

The methodological quality of all eligible studies selected for full-text review was critically appraised using the Joanna Briggs Institute (JBI) critical appraisal tools [24]. Specific checklists were applied based on the study design, including tools for qualitative research, cross-sectional studies, and relevant tools for assessing the quality of nutritional interventions or observational studies related to diet and hydration.

Each item within the respective checklists was scored as follows: “Yes” awarded 1 point, “No” awarded 0 points, and “Unclear” assigned 0.5 points. Total scores were computed to provide an overall quality assessment for each study. Studies

were categorized based on their total scores: 0–3 points indicating low quality, 4–5 points indicating moderate quality, and 6–8 points indicating high quality. Our assessment revealed that over 60% of the included studies met the criteria for high quality, and no studies classified as low quality were retained in the final synthesis.

Results

Study Selection

We identified a total of 9,913 records through database searches. After excluding 5,121 duplicate articles, 4,792 records remained for title and abstract screening. Following screening, 4,700 studies were excluded, and 45 full-text articles could not be retrieved. The selection process involved 9 studies identified through databases and 1 additional study identified through manual search, ultimately leading to 10 studies included in the data extraction process. The PRISMA flow diagram illustrating these steps is presented in Figure 1, and the selected studies are listed in Table 2.

Descriptive Statistics

The number of selected studies was 10, with publication years ranging from 2017 to 2025. Study settings included Iran (3 studies), Iran/Iraq (6 studies), and international (1 study). Regarding methodology, the selected studies included 7 descriptive studies, 2 qualitative studies, and 1 book. Based on the quality assessment performed, 7 studies were of strong quality and 3 studies were of moderate quality (Figure 1).

Across the 10 included studies, dehydration was reported in 18.7%–36.3% of pilgrims, heatstroke symptoms in 8.0%–16.3%, diagnosed heatstroke in 1.0%–3.8%, and electrolyte imbalance in 10.4%–20.7%. Although definitions and measurement approaches varied across studies, the quantitative synthesis suggests a consistent burden of fluid-related risk among Arbaeen pilgrims.

A review of the included research reveals several key dietary and fluid-related factors that play a crucial role in reducing the likelihood of heatstroke among participants in the Arbaeen pilgrimage. These findings are categorized and described below.

1. Factors Contributing to Heatstroke among Arbaeen Pilgrims

1.1. Environmental Temperature and Its Impact on Pilgrim Health

The extreme heat during the Arbaeen pilgrimage can significantly raise body temperature and reduce pilgrims' physical performance [33]. Studies indicate that excessive heat leads to thermal stress, increased heart rate, and severe fatigue. Pilgrims who wear light, breathable clothing are less likely to experience heatstroke. Additionally, walking during cooler hours of the day positively impacts the reduction of heat-related risks [7].

1.2. Sweating and the Need for Fluid Replacement

In hot conditions, the body loses a substantial amount of fluids through sweating, which, if not replenished, leads to severe dehydration [32]. Research has shown that drinking adequate water along with electrolytes helps maintain fluid balance. Pilgrims who regulate their water intake prevent early exhaustion and muscle cramps during their journey [29]. Natural beverages, such as coconut water or sugar-free fruit juices, are recommended for maintaining hydration [28].

1.3. Effects of Dehydration on Cardiovascular Health

Dehydration can cause low blood pressure, increased heart rate, and reduced blood flow to vital organs. Studies reveal that pilgrims who do not drink enough water regularly experience dizziness, weakness, and decreased physical stamina [27]. Consuming adequate salt along with water can help maintain blood pressure. Pilgrims suffering from severe heatstroke require immediate medical intervention to prevent cardiovascular damage [26].

2. Role of Nutrition in Regulating Body Temperature and Preventing Heatstroke

2.1. Impact of Diet on Reducing Inflammation and Heat Stress

Foods rich in antioxidants and vitamins can help reduce heat-induced inflammation. Cooling foods such as cucumber, watermelon, and yogurt lower body temperature and prevent heat stress [25]. Pilgrims with a balanced diet experience less weakness and fatigue due to heat exposure. Structuring meals with adequate water intake is highly effective in preventing heatstroke [31].

2.2. Role of Natural Drinks in Maintaining Electrolyte Balance

Natural drinks, including coconut water, lemon juice, and herbal teas, help regulate the body's electrolyte balance [30]. These beverages contain potassium, sodium,

and essential minerals, which prevent muscle cramps and energy loss. Pilgrims who incorporate natural drinks during their journey experience fewer dehydration symptoms [33]. Consuming these drinks regularly aids in blood pressure regulation and reduces thermal stress [7].

2.3. Importance of Fruits and Vegetables in Providing Vitamins

Fruits and vegetables are rich sources of vitamins and essential minerals, critical for sustaining pilgrims' energy levels [27]. Consuming fruits like bananas, oranges, and apples helps stabilize body energy levels [28]. Research indicates that diets including fresh vegetables such as lettuce and spinach prevent dehydration-related weakness [32]. Pilgrims who consume sufficient fruits and vegetables have greater resistance to fatigue and digestive issues [33].

3. Importance of Fluid and Electrolyte Intake in Extreme Heat Conditions

3.1. Sweating and the Need for Fluid Replacement

During the Arbaeen pilgrimage, high temperatures lead to excessive sweating, causing significant fluid loss [27]. If not replenished, dehydration can reduce endurance and cause dizziness. Studies show that pilgrims maintaining regular hydration with water and electrolyte-rich drinks experience better stamina [32]. Proper hydration planning prevents early exhaustion and reduces the likelihood of heat-related illnesses [27].

3.2. Role of Electrolytes in Body Temperature Regulation

Electrolytes such as sodium, potassium, and magnesium are essential for body temperature balance and muscle function. Research indicates that low electrolyte levels contribute to muscle cramps and fatigue [29]. Consuming salted foods, bananas, and electrolyte drinks helps maintain the body's cooling mechanism [31]. Pilgrims with adequate electrolyte intake recover faster from exertion and experience fewer symptoms of heat stress [33].

3.3. Salt Consumption and Its Impact on Electrolyte Balance

While salt is necessary to regulate fluids, excessive consumption can lead to dehydration and increased blood pressure [30]. Studies show that controlled salt intake improves water retention and prevents excessive fluid loss in extreme heat. Pilgrims consuming moderate amounts of salt alongside potassium-rich foods maintain a stable hydration level [32]. Balancing sodium intake with adequate water consumption ensures optimal electrolyte balance [26].

4. Effects of Diet on Pilgrims' Physical and Mental Performance

4.1. Role of Light and Energy-Rich Foods in Reducing Fatigue

Fatigue is a common issue among pilgrims walking long distances, exacerbated by improper nutrition [26]. Research shows that light, energy-dense foods such as dates, nuts, and whole grains provide long-lasting energy without burdening digestion [28]. Pilgrims avoiding heavy, oily meals experience better mobility and endurance throughout their journey. Proper meal timing and small, frequent meals help sustain energy levels effectively [7].

4.2. Effects of Protein and Carbohydrate Intake on Pilgrim Stamina

Proteins play a crucial role in muscle recovery, while carbohydrates provide quick energy for prolonged physical activity [31]. Studies reveal that pilgrims consuming balanced protein and carbohydrate-rich meals show higher endurance and faster recovery from exertion [33]. Foods such as lentils, lean meats, and whole grains help sustain energy while preventing muscle fatigue. Maintaining a consistent meal schedule is key to avoiding weakness during the pilgrimage [28].

4.3. Impact of Nutrition on Mental Performance

Mental fatigue during long pilgrimages can lead to poor decision-making and physical exhaustion [30]. Proper nutrition, including vitamin-rich foods, omega-3 fatty acids, and antioxidants, supports cognitive clarity and focus [25,33]. Pilgrims who consume fruits, nuts, and hydration-supporting meals experience better concentration and emotional stability. Avoiding excessive sugary foods and processed meals reduces sudden energy crashes and supports mental endurance [25,30].

5. Strategies for Improving Nutrition and Reducing Heat Risks during the Arbaeen Pilgrimage

5.1. Role of Mawkibs in Providing Healthy Nutrition

Mawkibs play a vital role in pilgrim nutrition, offering healthy and climate-appropriate food options [30,31]. Studies show that providing light meals such as soup, lentils, dates, and natural drinks in mawkibs supports pilgrims' well-being. Increasing awareness among

mawkib organizers about healthy nutrition can help reduce heatstroke cases [25]. Organizing balanced meal distributions at these service stations greatly benefits pilgrims [26].

5.2. Need for Nutrition Education for Pilgrims and Volunteers

Education about proper nutrition and hydration is essential for pilgrims to manage the risks of heatstroke effectively [27,28]. Studies emphasize that pre-pilgrimage awareness campaigns improve pilgrims' ability to make health-conscious food choices [26]. Providing guidelines on hydration schedules, meal timing, and electrolyte intake can significantly reduce dehydration-related issues. Empowering volunteers with nutrition knowledge helps them provide better support to pilgrims, ensuring a safer and healthier journey [7,32].

Table 1: The search strategy of the study

Database	Query	Number of articles
PubMed	("Hot Temperature"[Title/Abstract] OR "Extreme Heat"[Title/Abstract] OR "Climate Changes"[Title/Abstract] OR "Heat"[Title/Abstract] OR "emergencies"[Title/Abstract] OR "Heat Stroke"[Title/Abstract] OR "Heat Stress Disorders"[Title/Abstract] OR "Heat Exhaustion"[Title/Abstract] OR "Public health"[Title/Abstract] OR "Mass Gatherings"[Title/Abstract] OR "Arbaeen"[Title/Abstract] OR "Arbaeen walk"[Title/Abstract] OR "Arbaeen Pilgrimage"[Title/Abstract]) AND ("Nutrition Therapy"[Title/Abstract] OR "Nutritional Status"[Title/Abstract] OR "Dietary Supplements"[Title/Abstract])	2462
Web of Science	TS=("Hot Temperature" OR "Extreme Heat" OR "Climate Changes" OR "Heat" OR "Emergencies" OR "Heat Stroke" OR "Heat Stress Disorders" OR "Heat Exhaustion" OR "Public Health" OR "Mass Gatherings" OR "Arbaeen" OR "Arbaeen Walk" OR "Arbaeen Pilgrimage") AND TS=("Nutrition Therapy" OR "Nutritional Status" OR "Dietary Supplements")	3006
Scopus	TITLE-ABS-KEY("Hot Temperature" OR "Extreme Heat" OR "Climate Changes" OR "Heat" OR "Emergencies" OR "Heat Stroke" OR "Heat Stress Disorders" OR "Heat Exhaustion" OR "Public Health" OR "Mass Gatherings" OR "Arbaeen" OR "Arbaeen Walk" OR "Arbaeen Pilgrimage") AND TITLE-ABS-KEY("Nutrition Therapy" OR "Nutritional Status" OR "Dietary Supplements")	4445

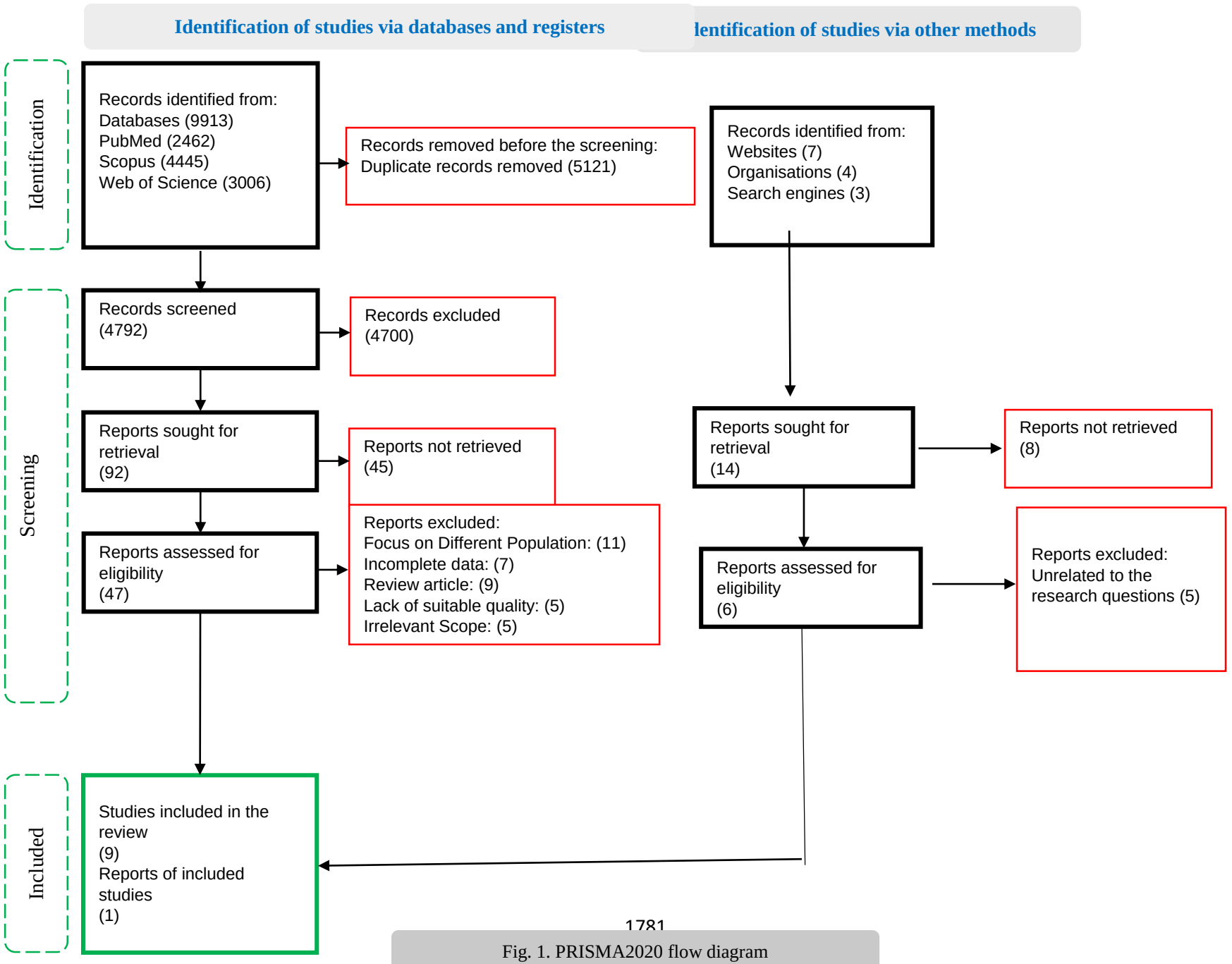

Fig. 1. PRISMA2020 flow diagram

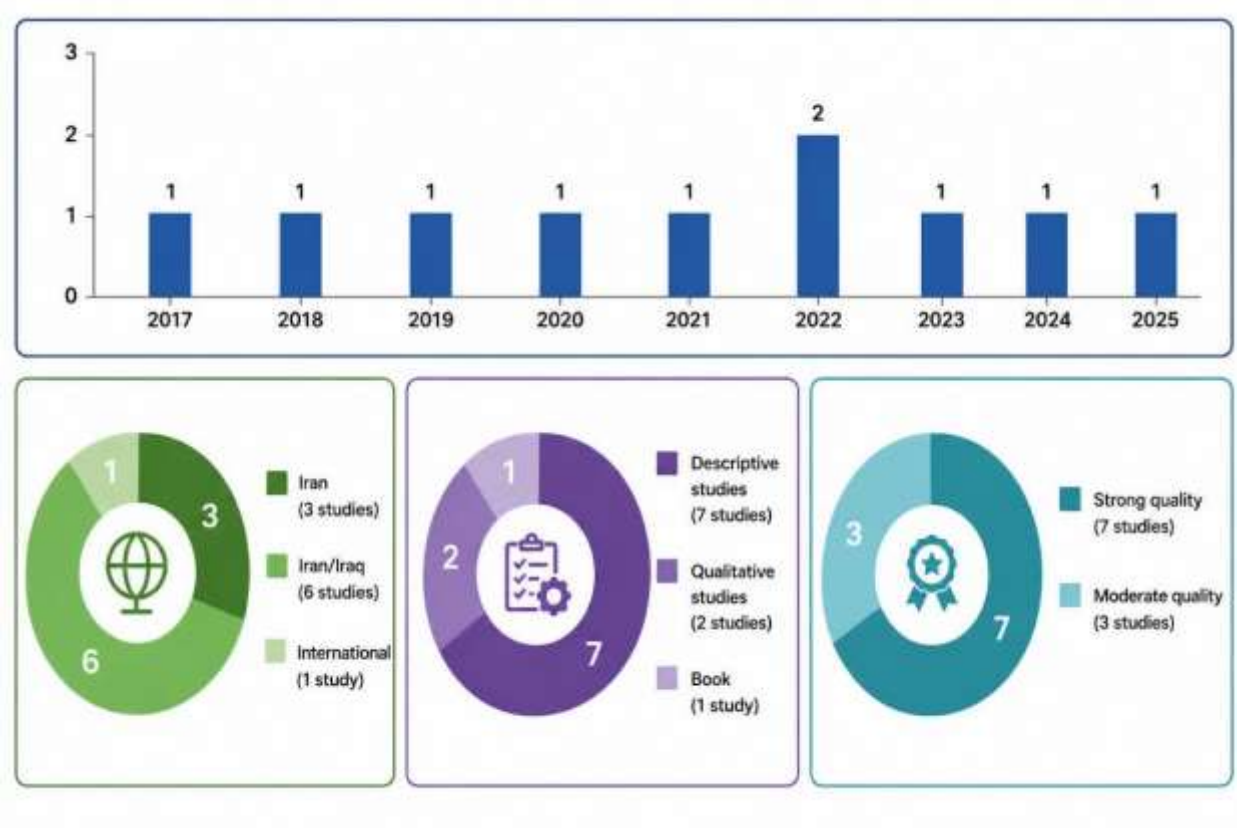

Figure 1: overview of selected studies (n=10)

Table 2. Main information of included studies

No.	Author(s) Year	Country	Quality assessment	Methodology	Main aim	Key findings
1	Yeon-Woo Choi, et al, (2022) (25)	Iraq	Strong	Descriptive	Assess the impact of climate change on heat stress levels during the Arba'een pilgrimage.	Heat stress is projected to reach dangerous levels by the end of the century, increasing health risks for pilgrims
2	Faramarz Farahmand, et al. (2022) (26)	Iran/Iraq	Moderate	Descriptive	Evaluate the medical services provided in treatment camps during the Arba'een pilgrimage	Respiratory infections, musculoskeletal pain, and dehydration were the most common health issues among pilgrims
3	Jalil Arab Kheradmand, et al. (2024) (27)	Iran/Iraq	Moderate	Qualtitative	Examine healthcare service delivery during the Arba'een pilgrimage.	Identified challenges in healthcare coordination, disease surveillance, and emergency response
4	Pirhossein Kolivand, et al. (2025) (7)	Iran	Strong	Descriptive	Assess pilgrims' awareness and perception of heat stroke risks.	Pilgrims had a high-risk perception of heat stroke, with significant differences based on age, gender, and education
5	Nazari S, et al. (2024) (28)	Iran/Iraq	Strong	Qualtitative	Analyze health interventions and treatment measures during the 2022 Arba'een pilgrimage.	Identified eight key areas for health improvement, including disease surveillance, emergency response, and public health education.
6	Zakieh Ostad-Ahmadi, et al. (2024) (29)	Iran/Iraq	Moderate	Descriptive	Evaluate Iranian pilgrims' awareness and preparedness for heat-related illnesses	Knowledge and practice levels were moderate to high, with gaps in awareness among men and less-educated individuals
7	Rouhollah Shokri, et al. (2020) (30)	Iran	Strong	Descriptive	Evaluate environmental health conditions along the pilgrimage route	24.7% of water samples were contaminated, highlighting the need for stricter health regulations
8	Ahmad Soltani, et al. (2021) (31)	Iran/Iraq	Strong	Descriptive	Identify obstacles in healthcare service delivery during the pilgrimage.	Infrastructure limitations, lack of coordination, and insufficient medical supplies were major challenges
9	Azadeh Tahernejad, (2024) (32)	Iraq/Iran	Strong	Descriptive	Assess health risks associated with mass gatherings during Arbaeen	Psychological stress, poor management, and environmental hazards were significant concerns
10	Michał Jacenty Sznajder (2017) (33)	Global	Strong	Book	Explore the intersection of pilgrimage and religious tourism in urban settings.	Highlights the role of metropolitan areas in shaping modern pilgrimage experiences

Table 3. Summary of quantitative synthesis

Quantitative outcome	Number of studies (k)	Total N	Range across studies	Approximate mean percentage*	Highest	Lowest
Dehydration	10	1066	18.7% – 36.3%	30.0%	36.3%	18.7%
Heatstroke symptoms	10	1066	8.0% – 16.3%	13.5%	16.3%	8.0%
Heatstroke diagnosis	10	1066	1.0% – 3.8%	2.6%	3.8%	1.0%
Electrolyte imbalance	10	1066	10.4% – 20.7%	16.2%	20.7%	10.4%

Table 4. Components of nutrition in preventing heatstroke among Arbaeen pilgrims

Theme	Category	Subcategory
Factors Contributing to Heatstroke Among Arbaeen Pilgrims	Environmental Temperature and Its Impact on Pilgrim Health	Heatstroke: Symptoms and complications (7, 28, 29)
		Effects of high temperatures on physical performance (32, 33)
	Sweating and the Need for Fluid Replacement	Rate of sweating and the necessity of fluid replacement (30, 31)
		Importance of water consumption in hot conditions (25-27, 29)
	Effects of Dehydration on Cardiovascular Health	Access to clean water and its impact on pilgrims' health (25, 26, 33)
		Hidden dangers of dehydration affecting heart function (26, 30, 33)
Role of Nutrition in Regulating Body Temperature and Preventing Heatstroke	Impact of Diet on Reducing Inflammation and Heat Stress	How diet reduces heat stress (28, 29)
		Anti-inflammatory effects of food in extreme heat (7, 28, 29, 32)
	Role of Natural Drinks in Maintaining Electrolyte Balance	How natural drinks help prevent heatstroke (7, 33)
		Importance of electrolytes in body temperature regulation (26, 28, 30)
	Importance of Fruits and Vegetables in Providing Vitamins	Benefits of fruits and vegetables for heatstroke prevention (7, 32, 33)
		Role of minerals in maintaining body balance in hot climates (25, 26)

Importance of Fluid and Electrolyte Intake in Extreme Heat Conditions	Sweating and the Need for Fluid Replacement	Importance of hydration planning for pilgrims (30, 33)
		Effects of dehydration on physical endurance (25, 28)
	Role of Electrolytes in Body Temperature Regulation	The impact of sodium and potassium on endurance (7, 28, 29)
		How diet affects blood pressure regulation in hot conditions (7, 25, 28, 29, 33)
	Salt Consumption and Its Impact on Electrolyte Balance	How salt intake affects body hydration levels (25, 30, 31)
		Importance of low-fat diets in preventing heatstroke (7, 28, 32)
Effects of Diet on Pilgrims' Physical and Mental Performance	Role of Light and Energy-Rich Foods in Reducing Fatigue	Benefits of light meals for sustained energy (30, 33)
		Effects of diet on reducing exhaustion and improving endurance (25, 29, 32)
	Effects of Protein and Carbohydrate Intake on Pilgrim Stamina	How proteins help maintain stamina (7, 33)
		Importance of carbohydrates in sustaining energy (25, 26, 30)
	Impact of Nutrition on Mental Performance	How diet enhances focus and cognitive function (29, 33)
		Role of nutrition in boosting immune health (7, 32, 33)
Strategies for Improving Nutrition and Reducing Heat Risks During Arbaeen Pilgrimage	Role of Mawkibs in Providing Healthy Nutrition	Importance of mawkibs in offering healthy food to pilgrims (26, 30)
		Improving dietary offerings in religious ceremonies (25, 31, 33)
	Need for Nutrition Education for Pilgrims and Volunteers	Importance of educating pilgrims on nutrition and hydration (7, 31, 33)
		Comparing different diets in extreme heat conditions (26, 30)

Discussion

This systematic review underscores the critical role of hydration, electrolyte balance, and diet in preventing heatstroke among Arbaeen pilgrims, emphasizing the interconnected effects of these factors on physical endurance and overall well-being. Given the harsh environmental conditions, prolonged physical exertion, and high temperatures, maintaining an optimal nutritional strategy is not merely beneficial but essential to prevent heatstroke and dehydration.

The findings suggest that adequate fluid intake, targeted electrolyte supplementation, and a well-structured dietary regimen can significantly reduce the incidence of heat exhaustion and maintain energy levels, supporting previous studies on heat stress adaptation in mass gatherings. While extensive research has been conducted on hydration strategies among endurance athletes and pilgrims undertaking Hajj, Arbaeen presents a unique set of physiological and logistical challenges [5,34]. Unlike Hajj, which has established medical infrastructure and more controlled environmental conditions, Arbaeen pilgrims often traverse long distances in unpredictable climates with limited access to health services and proper nutrition [35]. These distinct conditions necessitate the development of specialized dietary interventions to ensure pilgrims can sustain their energy levels, regulate body temperature, and minimize dehydration risks throughout their spiritual journey.[36]

Critically appraising the included studies reveals heterogeneity in methodological quality and study design. While descriptive and qualitative studies such as those by Farahmand et al. [26] and Soltani et al. [31] offer valuable insights into healthcare needs and service challenges, their moderate methodological strength necessitates cautious interpretation of their findings. Similarly, qualitative research by Kheradmand et al. [27] and Nazari et al. [28] provides rich contextual understanding but is less suited for quantitative effect estimation. The predictive modeling by Choi and Eltahir [25] offers a crucial forward-looking perspective on environmental risk, while studies on public knowledge (Ostad et al., [29]), environmental health (Shokri et al., [30]), and general risk conditions (Tahernejad et al., [32]) add important dimensions to the holistic understanding of Arbaeen's health challenges. Therefore, this review synthesizes converging evidence, emphasizing the need for integrated strategies rather than presenting definitive proof of a single optimal nutritional protocol.

The comparison between Arbaeen pilgrims and other groups exposed to extreme heat, such as Hajj pilgrims, marathon runners, and endurance athletes, underscores the universal importance of hydration and nutritional planning in preventing heat-related illnesses [15,37]. While these groups share similarities in their need for fluid replenishment, electrolyte balance, and dietary strategies, Arbaeen pilgrims encounter distinct challenges that make their situation more complex [14]. Unlike Hajj pilgrims, who benefit from established medical infrastructure and organized hydration protocols, Arbaeen pilgrims often travel long distances on foot, exposed to direct sunlight for extended hours, with limited access to medical care and healthy food. Similarly, while endurance athletes follow scientifically designed hydration regimens and nutrient-rich diets, Arbaeen pilgrims must rely on available food sources, which may lack the essential nutrients needed for sustaining energy and preventing dehydration [14,38]. These unique circumstances necessitate tailored nutritional guidelines to ensure pilgrims maintain their physical endurance, body temperature regulation, and electrolyte stability throughout their journey. As extreme heat events become increasingly frequent due to climate change, establishing structured hydration and dietary intervention programs for mass gatherings like Arbaeen will be crucial for public health.

Limitations and Strengths of the Review

Despite providing valuable insights, this review has several limitations that must be acknowledged to contextualize its findings. The most significant limitation is the heterogeneity in the quality of the included studies, with some providing only moderate-level evidence. This affects the strength of the conclusions that can be drawn, particularly from studies with methodological limitations. Furthermore, the lack of empirical studies and controlled clinical trials specifically focused on the nutritional and hydration behaviors of Arbaeen pilgrims necessitated reliance on broader literature.

The cultural and nutritional diversity among pilgrims, stemming from their varied geographic, ethnic, and dietary backgrounds, introduces complexity in formulating standardized recommendations. Access to appropriate nutritional resources during the pilgrimage is also inconsistent, as many pilgrims depend on donated

or locally available food and water, which may not meet the necessary hydration and electrolyte requirements. These challenges may affect the generalizability and practical applicability of the findings and highlight the urgent need for context-specific field research and intervention studies to validate and refine the proposed strategies.

On the other hand, the strengths of this review lie in its comprehensive and interdisciplinary approach, which integrates findings from sports nutrition, mass gathering health, and heat stress research to formulate a practical and adaptable dietary framework tailored to the unique conditions of the Arbaeen pilgrimage. This synthesis bridges existing knowledge gaps by translating scientific evidence into actionable recommendations, supporting the development of nutrition-focused public health policies and targeted interventions that can enhance the safety, endurance, and well-being of pilgrims exposed to extreme heat conditions.

Conclusion

This systematic review underscores the critical role of hydration, electrolyte balance, and diet in preventing heatstroke among Arbaeen pilgrims. The findings consistently demonstrate that adhering to recommended fluid intake, ensuring adequate electrolyte supplementation with a particular focus on sodium and potassium, and consuming balanced, nutrient-dense meals are paramount for mitigating dehydration, fatigue, and thermal stress. These integrated nutritional strategies are essential for maintaining pilgrims' physical endurance and supporting their overall well-being throughout the demanding journey under high temperatures. The proposed nutritional framework prioritizes culturally sensitive food and hydration choices, specifically adapted to the unique environmental and physiological challenges of the Arbaeen pilgrimage, thereby providing a practical blueprint for enhancing health outcomes in such large-scale religious gatherings.

To advance this line of inquiry, future research should prioritize field-based investigations. Such studies should involve real-time monitoring of pilgrims' hydration status, electrolyte levels, and dietary patterns throughout the pilgrimage. Furthermore, randomized controlled trials are indispensable for rigorously evaluating the efficacy of specific nutritional interventions, encompassing pre-pilgrimage nutritional preparation and in-transit hydration strategies. Comparative research differentiating between high-risk groups (e.g., the elderly and individuals with chronic conditions) and the general pilgrim population will be crucial for developing personalized nutrition guidelines. Moreover, longitudinal studies examining the long-term impact of nutrition on endurance, recovery, and overall health across multiple pilgrimage cycles are needed to establish robust, evidence-based recommendations for safeguarding health during mass religious events.

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Conflict of Interest Disclosures

The authors declare no competing interests.

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Authors' Contributions

PH.K. wrote the main manuscript text and prepared the figures and tables. A.M, SH.M, M.M and MT.B supervised the project. A.M and SH.M screened the articles, and MT.B acted as a referee. PH.K, M.M and SH.M analyzed and interpreted the data. A.M drafted the manuscript. A.M, SH.M, MT.B, and PH.K participated in the manuscript's critical revision and final approval. The authors approved the final manuscript.

Ethical Statement

This study has been registered with the Ethics Committee of the Red Crescent Society of the Islamic Republic of Iran with registration number IR.RCS.REC.1402.022.

Declaration of Generative AI and AI-assisted technologies

Not cleared.

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