Commentary

Heat Stroke and Hyperosmolar Hyperglycemia State: Two Faces of the Same Coin (Dehydration) in the Hajj Journey - How to Reduce Deaths Among Pilgrims

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Heat stroke (HS) and hyperosmolar hyperglycemic state (HHS) are critical conditions frequently affecting pilgrims during the Hajj, especially with temperatures exceeding 50°C (122°F). This brief commentary examines the interconnected risks of HS and HHS among Hajj pilgrims, focusing on the heightened vulnerability of those with diabetes. We discuss the mechanisms linking dehydration, hyperthermia, and hyperglycemia, emphasizing the need for early recognition and intervention. Preventive strategies such as heat acclimation, proper hydration, and probiotic-based oral rehydration solutions (ORSP) are highlighted. Additionally, the use of smart ID medical bracelets for diabetic patients can improve emergency response. Implementing these measures can reduce the incidence and severity of heat stroke and hyperosmolar hyperglycemic state, protecting the health of pilgrims.

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Abbreviations

- HS: heat stroke
- HHS: hyperosmolar hyperglycemia state
- ORSP: probiotic-based oral rehydration solution

 doi.org/10.32388/KVO26N

Introduction

Hajj is the annual religious pilgrimage considered the greatest journey for Muslims around the world. It fulfills a profound wish for many, as more than 2 million people from over 180 countries come to the holy city of Mecca, Saudi Arabia, each year.

Nowadays, the Hajj season indeed falls during the summer months, as is the case this year and next year, occurring in midsummer when extreme temperatures can soar above 50°C (122°F). This timing significantly amplifies the challenges faced by pilgrims, especially those managing diabetes. Every Muslim has a religious obligation to visit Makkah at least once in their lives. The fifth of Islam's five pillars is performing Hajj. The Holy Koran contains instructions on how the rituals should be performed correctly (ii, 193 ff). These regions experience average highs of 49°C (118°F) in June through September. [1]

This year, the Hajj in 1445H (2024) took place in June, during midsummer, with average high temperatures exceeding 50°C (122°F) during the first ten days. Heatstroke presents a significant challenge for citizens, pilgrims, and migrant workers during the Hajj season, particularly for the elderly with chronic conditions such as diabetes mellitus.

Heat stroke (HS) is a catastrophic condition with exceptionally high mortality, characterized by severe hyperthermia (> 40°C) and central nervous system abnormalities. It has taken attention worldwide in recent years [2].

Although active on-site cooling and targeted temperature management in the early stages of heatstroke (HS) can effectively slow its progression and reduce mortality, patients often face difficulties in obtaining effective cooling in real-world settings where heatstroke occurs. This can lead to severe heatstroke and, in some cases, death. It has been reported that the mortality rate among heatstroke patients in intensive care units can exceed 60%. If treatment is not initiated promptly, heatstroke can rapidly advance, often resulting in severe multiple-organ damage. Given the limited treatment options and poor prognosis, effective preventative measures are crucial for managing heatstroke. Heat acclimation (HA) is widely recognized as one of the best and most cost-effective strategies to prevent and protect against heatstroke, particularly among military personnel. [3]

The pathophysiology of HS entails a shift from a compensable thermoregulatory state to a non-compensatory one. Thermoregulatory failure aggravates the pathophysiological processes involved,

including severe inflammation, multiple organ injury, and disseminated intravascular coagulation, resulting from the combination of acute hyperthermia and circulatory collapse. [4]

A study by Lei Li et al. (2024) on a rat model of heat acclimation (HA) with oral rehydration solution plus probiotics (ORSP) found that HA can reduce heatstroke-induced intestinal lesions by inhibiting the NF-κB signaling pathway. We hypothesize that combining HA and ORSP will protect against heatstroke by mitigating the inflammatory response and gut barrier damage pathways through the modulation of intestinal flora and heat shock protein expression. In the future, we plan to investigate and validate these mechanisms from various perspectives. [5]

Although authorities are conducting research and forming interdisciplinary teams to prevent health problems during the Hajj, the mortality rate from heatstroke remains high, with the majority of patients exhibiting hyperthermia, various signs and symptoms, elevated creatinine levels, and electrolyte imbalances. [6]

Discussion

Hajj in the next years is a big challenge as temperatures during Hajj can exceed 50°C (122°F) in Mecca and surrounding areas for many years until they come back in the winter season according to a linear calendar; this extreme heat dramatically increases the risk of heat-related illnesses, including heat stroke. The heat stroke Hajj Challenges=Extreme Summer Heat +Physical Exertion+ Diabetes Management. Also, the risk of intensified dehydration risk =Extreme Heat ×Physical Exertion ×Diabetes-related Fluid Loss can happen among pilgrims.

Elderly patients are most susceptible to complications from heat illness, especially if they have chronic diseases like diabetes. Heat stroke and hyperosmolar hyperglycemia: two faces of the same coin in the Hajj journey. Like fire and water in the pilgrim's body, they struggle and cooperate. Heat ignites the body, while sugar dries out life. Both draw a map of danger on the walls of blood vessels. In a spiritual journey, the body becomes a delicate balance between the heat of faith and the sweetness of patience."

Hyperosmolar hyperglycemic state (HHS) is a serious complication of **diabetes** that happens when blood sugar levels are very high for a long period (8).

Hyperosmolar hyperglycemic state (HHS) can indeed be a precipitating factor that increases the severity of heat stroke. Both conditions share common risk factors and can exacerbate each other.

Without prompt treatment, heat stroke (HS) can lead to serious complications, including cerebral edema, electrolyte imbalances, myocardial infarction, stroke, seizures, and central pontine myelinolysis. These severe outcomes emphasize the urgent need for immediate and effective medical intervention to prevent potentially life-threatening consequences and ensure the best possible recovery for affected individuals [7]. Here's how they are interrelated: heat stroke is a factor predisposing to HHS.

Hyperglycemia significantly increases the risk of stroke, particularly in individuals with diabetes. This elevated risk is linked to poorer clinical outcomes, including higher mortality rates, especially after an ischemic stroke. Effective management of blood glucose levels is crucial for improving outcomes and reducing the likelihood of severe complications following a stroke [8].

Hyperglycemia indeed accelerates the effects of heat stroke, creating a dangerous synergy that can significantly increase health risks, especially during physically demanding events like the Hajj pilgrimage. Let me elaborate on this important point:

The physiological changes can occur for diabetic patients exposed to heat stroke:

1. **Dehydration Amplification:** Hyperglycemia exacerbates dehydration through osmotic diuresis, which increases urine output and fluid loss [9]. This effect worsens the dehydration caused by excessive sweating in hot conditions. The combined impact of hyperglycemia and fluid loss accelerates the onset of heat stroke symptoms. Hyperglycemic Hyperosmolar State (HHS) is characterized by severe hyperglycemia and dehydration, where elevated blood sugar levels lead to significant fluid loss. Heat stroke, similarly, involves dehydration resulting from excessive sweating and inadequate fluid intake in response to high environmental temperatures.
2. **Impaired Thermoregulation and damage to blood vessels:** Certain complications of diabetes, such as damage to blood vessels and nerves [10], can impair the function of sweat glands, reducing the body's ability to cool itself effectively. This impairment increases the risk of heat exhaustion and heat stroke, both of which are medical emergencies. People with diabetes are more prone to rapid dehydration, which heightens their risk during the Hajj pilgrimage. Effective management is crucial and includes staying hydrated, monitoring blood sugar levels, and taking regular breaks in shaded or air-conditioned areas to mitigate these risks. In Hyperglycemic Hyperosmolar State (HHS), the body's ability to dissipate heat is compromised due to

dehydration and elevated blood sugar levels. Similarly, in heat stroke, the body's thermoregulatory mechanisms fail, leading to a dangerous rise in core body temperature.

3. **Electrolyte Imbalance:** Both heat stroke and hyperglycemia lead to electrolyte imbalances [11], prolonged exposure to the sun can cause excessive sweating, leading to a significant loss of essential electrolytes in the body. As the body expels sweat and these crucial electrolytes, it increases the risk of heat-related issues, such as heat cramps. This loss of electrolytes disrupts normal muscle function and fluid balance, contributing to further complications and discomfort.

The combined effect can be more severe, leading to cardiac arrhythmias and neurological symptoms.

4. **Increased Metabolic Rate:** Hyperglycemia can cause metabolic disturbances and elevate the body's metabolic rate [12][13], which exacerbates the response to heat. In the Hyperglycemic Hyperosmolar State (HHS), the increased metabolic demand due to elevated blood sugar levels worsens the body's ability to handle heat. Similarly, in heat stroke, the heightened metabolic rate resulting from high temperatures further stresses the body, creating a vicious cycle of worsening symptoms. This increased metabolic activity generates more internal heat, accelerating the progression of heat stroke and compounding the risk of severe complications.
5. **Inflammation and Oxidative Stress:**

   Both conditions promote inflammation and oxidative stress in the body.

   This can lead to more rapid and severe cellular damage, accelerating the harmful effects of heat stroke.
6. **Compromised Cardiovascular Function:**

   Hyperglycemia can damage blood vessels and impair cardiovascular function.

   This makes it harder for the body to efficiently distribute blood to the skin for cooling, accelerating heat accumulation.

Preventive measures

Despite extensive efforts by health authorities in Saudi Arabia, including providing free medical services and establishing health facilities throughout the Hajj region, heat stroke remains a significant challenge during the intense summer heat. Preventive measures are crucial, especially for those with diabetes or at risk of hyperglycemia. Pilgrims should ensure adequate hydration, monitor blood sugar levels regularly, stay in cool environments, and carry necessary medical supplies. Education on recognizing symptoms of heat stroke and hyperglycemic emergencies is essential, as is having a plan

for immediate medical intervention. Screening all patients exposed to heat for diabetes and using specific medical bracelets for diabetic individuals can expedite emergency care by healthcare professionals. By understanding how hyperglycemia exacerbates heat stroke, both pilgrims and healthcare providers can better prepare for and mitigate these risks during the Hajj pilgrimage.

Heat stroke (HS) is a life-threatening condition characterized by a shift from a manageable to an unmanageable thermoregulatory state. This failure in thermoregulation intensifies underlying pathophysiological processes, leading to severe inflammation, multiple organ damage, and disseminated intravascular coagulation, all stemming from extreme hyperthermia and circulatory collapse [14]. While prompt detection and effective on-site cooling are usually sufficient to reverse organ dysfunction caused by HS, limited resources can impede cooling efforts and prevent full recovery. Once HS advances to systemic inflammation and multiple organ failure, even the most intensive treatments may not be enough to save the patient, highlighting the critical importance of early preventive strategies.

Studies have shown that supplementing with probiotics for 7 days can significantly alter gut microbiota and sustain the intestinal barrier, helping to prevent HS onset. Pretreatment with ORSIII has been demonstrated to prevent HS-induced intestinal lesions, as indicated by various serum biochemical markers and I-FBAP levels [15]. Additionally, research has revealed that HS can lead to kidney injury, but ORSIII (probiotics-based ORS supplementation) can alleviate this damage, as measured by Cr, BU, and NGAL levels [16]. ORS intake during exercise in hot conditions can reduce muscle cramp susceptibility, and ORS consumption during outdoor work has effectively prevented industrial accidents and HS in high-temperature environments, underscoring the importance of electrolyte-rich beverages in such conditions [17].

Since pilgrims come from different linguistic backgrounds around the world, communication can be challenging, especially in emergencies that require quick intervention from medical staff, which could pose a risk to the lives of the pilgrims. Therefore, we recommend using smart ID medical bracelets specific for diabetic patients and with specific colors according to the type of diabetes, either type 1 (green) or type 2 (yellow), to identify individuals with diabetes, making it easier for medical personnel to recognize them promptly.

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Declarations

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.