

How to Cite

Alanazi, N. (2026). Heat Stress: A Critical Medical Condition – The Key Role of Emergency Medical Services in Managing the Case. *International Journal of Health & Medical Sciences*, 9(1), 1-12.
<https://doi.org/10.21744/ijhms.v9n1.2452>

Heat stress: A Critical Medical Condition – The Key Role of Emergency Medical Services in Managing the Case

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Abstract---Heat stress is a critical and potentially life-threatening medical condition that occurs when the body's thermoregulatory mechanisms fail to dissipate excessive heat, resulting in elevated core body temperature and systemic dysfunction. This paper examines heat stress as a medical emergency, focusing on its pathophysiology, epidemiological trends, and the crucial role of Emergency Medical Services (EMS) in early recognition, prehospital management, and coordination of care. The study synthesizes current evidence from international health authorities, including the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and the Saudi Ministry of Health (MOH), to establish a comprehensive understanding of heat-related illness management. It emphasizes the integration of EMS systems in Saudi Arabia, where environmental heat exposure and mass gatherings present unique challenges. The findings underscore the importance of timely field cooling, rapid transport, and continuous training for EMS personnel to mitigate morbidity and mortality associated with heat emergencies.

Keywords---Heat Stress, Heat Stroke, Emergency Medical Services, Prehospital Care, Saudi Arabia, Public Health

Introduction

Heat stress has become a growing global concern due to rising ambient temperatures, urbanization, and an increase in outdoor occupational and recreational activities. The World Health Organization (2024) classifies heat-related illness as a major environmental health threat, contributing to more than 489,000 annual deaths worldwide. In Saudi Arabia, where summer temperatures routinely exceed 45°C, heat stress represents a persistent challenge to both the general population and emergency responders, particularly during large-scale events such as Hajj and Umrah.

Heat stress encompasses a spectrum of disorders ranging from mild heat exhaustion to life-threatening heat stroke. The condition occurs when the body's thermoregulatory system is overwhelmed by excessive environmental heat or metabolic production, leading to progressive dehydration, electrolyte imbalance, and multi-organ dysfunction. In the absence of timely intervention, severe heat stress can progress rapidly to neurological impairment, circulatory collapse, and death (CDC, 2023).

Emergency Medical Services (EMS) play a critical role in mitigating the impact of heat stress by providing early recognition, prehospital cooling, and safe patient transport to definitive care facilities. The Saudi EMS system, operated through agencies such as the Saudi Red Crescent Authority (SRCA) and the Ministry of National Guard Health Affairs (MNGHA), serves as the front line of response for heat-related emergencies. As global climate patterns continue to intensify, optimizing EMS readiness, training, and coordination is essential for effective prevention and management of heat-related medical emergencies.

This paper aims to examine the pathophysiology, clinical features, and management of heat stress, with a focus on the operational role of EMS in Saudi Arabia and internationally. Through literature review and analysis of case studies, the paper provides evidence-based recommendations to enhance field protocols, training curricula, and interagency coordination during heat emergencies (Brotherhood, 2008).

Pathophysiology of Heat Stress

Heat stress arises when the body's thermoregulatory capacity becomes overwhelmed due to excessive heat load, resulting in progressive elevation of the core temperature. Under normal physiological conditions, the hypothalamus maintains thermal balance through vasodilation, sweating, and increased cardiac output to dissipate heat. However, when the environmental temperature and humidity exceed the body's ability to regulate, these compensatory mechanisms fail, leading to a state of hyperthermia.

At the cellular level, heat stress disrupts protein structure, impairs enzymatic activity, and initiates inflammatory cascades. High temperatures cause denaturation of intracellular proteins, which triggers the expression of heat shock proteins (HSPs) that serve as molecular chaperones to stabilize cellular structures. If heat exposure persists, these protective responses are exhausted, resulting in mitochondrial dysfunction, oxidative stress, and apoptosis. Vascular permeability increases, allowing plasma leakage and leading to hypovolemia and electrolyte imbalance.

The central nervous system (CNS) is particularly sensitive to heat injury. Hyperthermia induces cerebral edema, blood-brain barrier disruption, and neuronal degeneration, which explain the altered mental status and seizures often seen in heat stroke. Furthermore, the cardiovascular system experiences significant strain; tachycardia and peripheral vasodilation increase cardiac workload, while dehydration and reduced venous return may precipitate circulatory collapse.

Systemically, heat stress activates the acute-phase response characterized by cytokine release—particularly interleukin-1 β , interleukin-6, and tumor necrosis factor-alpha (TNF- α). This cytokine storm contributes to systemic inflammatory response syndrome (SIRS), which can progress to multiple organ dysfunction syndrome (MODS). The liver, kidneys, and coagulation pathways are especially vulnerable, predisposing patients to rhabdomyolysis, acute renal failure, and disseminated intravascular coagulation (DIC).

In severe cases, untreated heat stress advances to classic or exertional heat stroke, defined by a core temperature exceeding 40°C with central nervous system dysfunction. Without immediate cooling and fluid resuscitation, irreversible damage to the brain, heart, and kidneys occurs within minutes, leading to high mortality rates.

Understanding the pathophysiology of heat stress is fundamental for Emergency Medical Services (EMS) personnel. Knowledge of these mechanisms allows responders to recognize the early physiological signs of decompensation and implement effective cooling and resuscitation measures in the prehospital phase. By addressing the pathophysiological basis of the condition, EMS providers can significantly reduce the risk of organ failure and death during heat-related emergencies (Gaudio & Grissom, 2016).

Epidemiology and Risk Factors

Heat stress remains a major global public health challenge, contributing to thousands of deaths and hospitalizations annually. The World Health Organization (WHO, 2023) estimates that between 2000 and 2020, the incidence of heat-related illnesses increased by more than 50% due to global climate change and urban expansion. Countries within the Middle East, South Asia, and parts of Africa face particularly high risk due to extreme temperatures, high humidity, and limited access to cooling infrastructure.

In Saudi Arabia, heat stress is a recurrent concern, particularly during the summer months and during major religious events such as Hajj and Umrah. Reports from the Saudi Ministry of Health (MOH, 2022) indicate that hundreds of pilgrims experience heat-related conditions each year, ranging from mild heat exhaustion to severe heat stroke. Environmental monitoring conducted by the National Center for Meteorology (NCM) shows that ambient temperatures can exceed 50°C in several regions, especially in Makkah, Madinah, and the Eastern Province.

Occupational exposure is another major determinant of heat stress prevalence. Workers in construction, transportation, agriculture, and oil industries are highly vulnerable due to prolonged outdoor exposure and heavy physical exertion. A cross-sectional study conducted in Riyadh by Alghamdi et al. (2021) found that 37% of outdoor laborers reported at least one heat-related illness episode during the summer season. The combination of high metabolic activity, inadequate hydration, and poor ventilation creates a significant cumulative heat burden.

Individual susceptibility factors further modify the risk of heat stress. Elderly individuals, children, people with chronic cardiovascular or renal disease, and those taking diuretics or beta-blockers are particularly susceptible. Body composition, acclimatization level, and fitness also play a role in thermoregulation efficiency. Additionally, social determinants such as housing conditions, economic status, and awareness level significantly influence population vulnerability (Wang et al., 2010).

The epidemiological trend demonstrates a seasonal and geographical clustering of heat-related illnesses. Peak incidence occurs between May and September, aligning with Saudi Arabia's hottest months. Data from the Saudi

Red Crescent Authority (SRCA, 2023) reveal an increased frequency of EMS dispatches for heat emergencies during these months, particularly in urban centers and mass gathering sites.

Globally, urban heat islands have amplified local temperature gradients, increasing the burden of heat-related morbidity in densely populated cities. Climate projections suggest that by 2050, the frequency of extreme heat events will double, disproportionately affecting regions such as the Arabian Peninsula. This underscores the urgent need for adaptive public health strategies, urban planning modifications, and strengthening of prehospital and emergency response systems to reduce morbidity and mortality associated with heat stress.

Clinical Presentation and Diagnosis

The clinical presentation of heat stress varies across a continuum from mild heat exhaustion to life-threatening heat stroke. Recognizing the spectrum of symptoms is crucial for Emergency Medical Services (EMS) personnel to ensure timely diagnosis and management in prehospital settings. Early manifestations of heat stress include generalized weakness, dizziness, excessive sweating, thirst, and muscle cramps. As the condition progresses, dehydration and electrolyte imbalance cause tachycardia, hypotension, and decreased urine output. Patients may complain of nausea, vomiting, and confusion, particularly in prolonged exposure scenarios or during high-intensity physical exertion.

Heat exhaustion typically presents with a core temperature between 37.5°C and 40°C. Patients are often diaphoretic with cool, moist skin and exhibit mild to moderate hypotension. Laboratory findings may reveal elevated hematocrit, mild hyponatremia, and increased serum creatine kinase (CK) levels due to early muscle injury.

In contrast, heat stroke represents the most severe form of heat-related illness and is defined by a core body temperature exceeding 40°C accompanied by central nervous system (CNS) dysfunction. Clinical features include altered mental status, ranging from confusion and agitation to seizures and coma. The skin becomes hot and dry due to failure of sweat mechanisms. Multisystem complications—such as rhabdomyolysis, acute renal injury, hepatic failure, and coagulopathy—are common in severe cases (WHO, 2023).

Diagnosis of heat stress is primarily clinical but must be supported by a thorough patient history, environmental context, and focused physical examination. In prehospital settings, accurate temperature measurement using rectal thermometers remains the gold standard. Core temperature monitoring allows differentiation between heat exhaustion and heat stroke, which is critical for guiding management (Bahanshel et al., 2018).

Laboratory investigations, when available in hospital settings, include serum electrolytes, renal and hepatic function tests, coagulation profile, and creatine kinase levels. Urinalysis may show myoglobinuria, indicating rhabdomyolysis. Electrocardiography (ECG) may reveal sinus tachycardia or electrolyte-related arrhythmias.

Differential diagnosis should include other causes of hyperthermia, such as sepsis, neuroleptic malignant syndrome, malignant hyperthermia, and thyroid storm. A detailed history regarding recent exertion, medication use, and environmental exposure assists in differentiating these conditions.

For EMS professionals, the diagnostic focus lies in early recognition of heat emergencies based on environmental exposure, vital signs, and neurological status. Prompt identification of heat stroke is vital, as mortality can exceed 50% without immediate intervention. By integrating rapid assessment protocols, EMS providers can initiate cooling and resuscitation within the critical therapeutic window to prevent irreversible organ injury and improve survival outcomes.

Heat Exhaustion vs. Heat Stroke

Parameter	Heat Exhaustion	Heat Stroke
Core Body Temperature	37.5°C – 40°C	> 40°C
Skin Condition	Cool, moist, profuse sweating	Hot, dry (sweating may be absent)
Neurological Findings	Mild confusion, dizziness, fatigue	Severe confusion, seizures, coma

Parameter Heat Exhaustion Heat Stroke

Core Body Temperature: 37.5°C – 40°C > 40°C

Skin Condition: Cool, moist, profuse sweating Hot, dry (sweating may be absent)

Neurological Findings: Mild confusion, dizziness, fatigue. Severe confusion, seizures, coma

Clinically, differentiating between these two stages determines the urgency and type of intervention. Patients with heat exhaustion respond well to rest, oral or intravenous fluid replacement, and removal from the heat source. Conversely, heat stroke demands immediate aggressive cooling measures, airway support, and rapid hospital

transport. EMS personnel must be trained to recognize this distinction promptly, as delayed management of heat stroke significantly increases morbidity and mortality rates.

Preventive education focusing on hydration, acclimatization, and early symptom recognition remains essential to reducing the incidence and severity of both conditions.

Complications and Mortality Trends

Heat stress and its severe manifestation, heat stroke, can lead to a wide range of systemic complications that significantly increase morbidity and mortality. The severity and rapidity of onset depend on the intensity of heat exposure, duration, and the timeliness of emergency intervention. Once the body's core temperature exceeds 40°C, multiple organ systems begin to fail as a result of direct thermal injury and secondary inflammatory cascades.

The most frequent complications involve the central nervous system (CNS), cardiovascular system, renal system, hepatic function, and coagulation pathways. Neurologically, patients may develop cerebral edema, seizures, or permanent cognitive deficits resulting from neuronal necrosis. Cardiovascular manifestations include arrhythmias, hypotension, and myocardial ischemia caused by dehydration and hypovolemia. Prolonged circulatory collapse may result in multi-organ dysfunction syndrome (MODS) and death (WHO, 2024).

Renal complications are common due to rhabdomyolysis and myoglobinuria, which cause acute tubular necrosis. Studies from the Saudi Ministry of Health (MOH, 2023) highlight acute kidney injury (AKI) as a leading cause of prolonged hospitalization among patients with heat stroke. Similarly, hepatic dysfunction manifests through elevated liver enzymes, jaundice, and disseminated intravascular coagulation (DIC), reflecting systemic inflammatory response syndrome (SIRS) and microvascular injury.

The hematologic complications of heat stroke include platelet consumption and coagulopathy. As the endothelial lining is damaged, disseminated intravascular coagulation develops, contributing to bleeding tendencies and worsening prognosis. Gastrointestinal mucosal ischemia can result in the translocation of bacteria into the bloodstream, further increasing the risk of sepsis.

Mortality trends associated with heat stress vary globally depending on climate, healthcare accessibility, and emergency response efficiency. According to the Centers for Disease Control and Prevention (CDC, 2023), the case fatality rate of untreated heat stroke can exceed 50%. However, prompt cooling within 30 minutes of symptom onset can reduce mortality to below 10%. In Saudi Arabia, national surveillance data (SRCA, 2023) indicate that fatalities from heat stroke are more frequent among elderly individuals, pilgrims, and outdoor laborers during peak summer months.

Between 2010 and 2020, the World Health Organization (WHO, 2022) documented a 30% rise in heat-related deaths worldwide, with the Middle East showing the highest regional increase. The combination of extreme temperatures, urban heat islands, and insufficient adaptation strategies continues to challenge healthcare systems. These data underscore the urgent need for robust early-warning systems, public health awareness campaigns, and strengthened EMS capacity to identify and treat heat stress before complications arise.

In summary, complications of heat stress are multi-systemic and potentially fatal if not promptly recognized and managed. Early prehospital interventions—such as rapid cooling, fluid resuscitation, and timely hospital transfer—are essential to prevent irreversible organ damage and reduce mortality rates associated with this preventable medical emergency.

The Role of Emergency Medical Services (EMS)

Emergency Medical Services (EMS) play a decisive role in the management of heat stress and heat-related illnesses. As the first point of contact for many patients, EMS personnel are tasked with early recognition, triage, stabilization, and rapid initiation of cooling interventions before hospital arrival. Their ability to act within the critical therapeutic window often determines survival and neurological outcomes.

The primary objectives of EMS in managing heat stress include: rapid assessment of vital signs, identification of core hyperthermia, and immediate initiation of active cooling techniques. Field providers are trained to assess the severity of illness based on temperature, level of consciousness, and hemodynamic stability. According to the Saudi Red Crescent Authority (SRCA, 2023), adherence to structured prehospital care algorithms has significantly improved patient survival during mass gatherings such as Hajj and Umrah.

The first step in prehospital care involves removing the patient from the heat source and initiating passive and active cooling methods. Passive cooling includes loosening clothing, fanning, and relocation to a shaded or air-conditioned area, while active cooling techniques include cold-water immersion, evaporative cooling, and ice-pack

placement in the axillae and groin regions. These interventions must be initiated immediately at the scene without delaying transportation.

Airway, breathing, and circulation (ABCs) assessment remains central to EMS management. Oxygen supplementation, intravenous fluid resuscitation with isotonic saline, and continuous cardiac monitoring are essential. Aggressive cooling should continue until the patient's core temperature decreases to approximately 38.5°C, at which point active cooling is discontinued to prevent rebound hypothermia. The use of antipyretics such as acetaminophen is contraindicated, as the mechanism of hyperthermia in heat stroke is not pyrogen-mediated.

Effective communication and coordination between prehospital providers and receiving hospitals are critical for seamless patient handover. Advanced notification allows emergency departments to prepare for continued cooling, laboratory evaluation, and management of potential complications such as renal failure or coagulopathy. In Saudi Arabia, EMS coordination with the Ministry of Health (MOH) and the Ministry of National Guard Health Affairs (MNGHA) ensures standardized response protocols and facilitates the integration of field and hospital care.

Training and preparedness are essential pillars of EMS effectiveness. Ongoing education programs—led by the Saudi Commission for Health Specialties (SCFHS)—emphasize recognition of environmental emergencies, simulation-based training, and the use of field triage tools. Evidence from multiple field studies indicates that simulation-based EMS education enhances team performance and reduces prehospital mortality in heat emergencies (Alharbi et al., 2022).

Moreover, the deployment of mobile command units and advanced communication systems during major public events enhances EMS situational awareness and resource distribution. Integration of GPS-based dispatch systems and real-time data monitoring allows rapid deployment of cooling units and medical teams to high-risk zones. These measures have been instrumental in maintaining low mortality rates during extreme heat conditions in Saudi Arabia.

In conclusion, EMS personnel serve as the cornerstone of effective heat stress management. Their rapid assessment, early initiation of cooling, and continuous coordination with hospitals significantly reduce morbidity and mortality associated with heat stroke. Continuous training, technological innovation, and interagency cooperation remain essential to sustaining high-quality prehospital care in the face of escalating global temperatures.

Prehospital Management Protocol

Effective prehospital management of heat stress is vital in reducing morbidity and mortality. Emergency Medical Services (EMS) personnel must adhere to structured, evidence-based protocols that emphasize early recognition, rapid cooling, and stabilization prior to hospital transfer. The success of these interventions depends on timely action, coordination, and the proper application of available resources.

The following key steps summarize the standardized prehospital management protocol adopted by EMS systems in Saudi Arabia and internationally:

1. **Scene Safety and Initial Assessment:**

Ensure the environment is safe for both responders and the patient. Move the patient away from direct heat exposure to a shaded or air-conditioned area. Assess responsiveness, airway, breathing, and circulation (ABCs). Record vital signs and obtain a rapid medical history, including duration of exposure, physical exertion, medications, and hydration status.

2. **Immediate Cooling Measures:**

Cooling should begin immediately at the scene without waiting for hospital arrival. Preferred methods include cold-water immersion (if feasible), evaporative cooling using water mist and fans, and application of ice packs to major vascular areas such as the neck, axillae, and groin. In the Saudi prehospital setting, portable misting and cooling tents have been deployed during Hajj and Umrah seasons with proven effectiveness (MOH, 2023).

3. **Airway and Oxygen Support:**

Maintain airway patency and administer supplemental oxygen if saturation drops below 94%. Intubation should be considered in patients with altered mental status or respiratory compromise. Avoid hyperventilation, as it may exacerbate metabolic alkalosis and impair perfusion.

4. **Fluid Resuscitation:**

Initiate intravenous (IV) access and administer isotonic saline (0.9% NaCl) to correct hypovolemia and electrolyte imbalance. Fluid replacement should be guided by hemodynamic parameters and urine output, avoiding overhydration that could lead to pulmonary edema.

5. **Monitoring and Transport:**

Continuously monitor heart rate, blood pressure, temperature, and level of consciousness during transport. EMS teams should communicate with the receiving hospital to prepare for advanced management, including laboratory investigations and potential complications such as rhabdomyolysis or renal failure.

6. ****Medication and Special Considerations:****

Antipyretics such as acetaminophen or ibuprofen are ineffective and should be avoided. Benzodiazepines may be used cautiously to control seizures or agitation. Cooling should be terminated once core temperature reaches approximately 38.5°C to prevent hypothermia.

7. ****Documentation and Handover:****

Accurate documentation of environmental conditions, prehospital interventions, and patient response is essential. Upon arrival, EMS personnel must provide a structured handover using the SBAR (Situation, Background, Assessment, Recommendation) format to ensure continuity of care.

In Saudi Arabia, these protocols are standardized through national EMS guidelines jointly issued by the Saudi Red Crescent Authority (SRCA) and the Ministry of Health (MOH). These guidelines align with international standards recommended by the World Health Organization (WHO) and the National Association of Emergency Medical Technicians (NAEMT). Continuous updates are made annually based on post-incident analyses conducted after large-scale events such as the Hajj and major sporting activities.

Ultimately, adherence to prehospital management protocols ensures that patients with heat stress receive timely, standardized, and effective care. Training EMS personnel to apply these protocols confidently under high-stress conditions significantly improves patient survival and reduces long-term complications.

Coordination with Hospitals (MOH, NGHA, SCFHS)

Effective coordination between Emergency Medical Services (EMS) and hospital facilities is critical in ensuring seamless patient care for heat-related illnesses. The continuum of care—from prehospital stabilization to definitive in-hospital management—depends on structured communication, standardized protocols, and interagency collaboration. In Saudi Arabia, coordination between EMS and major health authorities, including the Ministry of Health (MOH), the Ministry of National Guard Health Affairs (MNGHA), and the Saudi Commission for Health Specialties (SCFHS), plays a pivotal role in improving outcomes for heat stress patients.

The MOH oversees the national emergency response network, ensuring that EMS systems adhere to unified triage and referral guidelines. It mandates that all suspected heat stroke cases receive immediate cooling measures before hospital transport and that receiving facilities be notified in advance. This pre-arrival communication allows hospital teams to prepare rapid response units, intensive care beds, and laboratory support for critical cases (MOH, 2023).

The Ministry of National Guard Health Affairs (MNGHA) complements this framework through its advanced hospital-based EMS integration system. In Riyadh and other major regions, MNGHA facilities maintain direct radio and digital communication with field EMS teams. This coordination ensures real-time updates on patient condition, treatment progress, and estimated arrival time. The implementation of digital patient tracking systems—using mobile tablets and the ANAT platform—has further enhanced data accuracy and continuity of care (MNGHA, 2024).

The Saudi Commission for Health Specialties (SCFHS) plays an essential regulatory and educational role. It establishes competency-based training standards for paramedics, nurses, and emergency physicians in heat-related emergencies. Through its Continuing Professional Development (CPD) programs, SCFHS ensures that EMS personnel remain updated with the latest clinical guidelines, including cooling protocols, fluid management strategies, and recognition of early signs of organ dysfunction.

Coordination protocols are also reinforced through joint simulation exercises conducted by MOH, SRCA, and MNGHA during high-risk seasons, particularly before the Hajj period. These drills simulate large-scale heat emergencies, enabling cross-agency teams to test communication systems, logistical preparedness, and patient evacuation routes. Post-exercise evaluations provide data-driven insights that inform annual revisions of national heat emergency guidelines.

International collaboration further strengthens the Saudi model. Partnerships with the World Health Organization (WHO) and the U.S. Centers for Disease Control and Prevention (CDC) provide access to evidence-based global best practices. This has led to the adoption of standardized early-warning systems, thermal stress indices, and national awareness campaigns targeting outdoor workers and pilgrims.

In summary, effective coordination between EMS and hospital systems—under the guidance of MOH, MNGHA, and SCFHS—ensures rapid, structured, and life-saving interventions for heat stress patients. Continuous integration of digital systems, standardized training, and collaborative simulations represent the cornerstone of Saudi Arabia's advanced and adaptive emergency medical framework.

Training and Preparedness (SCFHS Standards)

Training and preparedness form the foundation of an effective response to heat-related medical emergencies. Within Saudi Arabia, the Saudi Commission for Health Specialties (SCFHS) plays a leading role in ensuring that all Emergency Medical Services (EMS) personnel, nurses, and physicians meet standardized competencies related to heat stress recognition, management, and prevention.

The SCFHS mandates competency-based training programs as part of the national EMS certification process. These programs emphasize both theoretical and practical aspects of environmental emergency medicine. The curriculum includes modules on the pathophysiology of heat stress, prehospital cooling protocols, rapid triage, and advanced airway management in hyperthermic patients. Practical simulations are conducted to replicate real-world conditions such as high ambient temperatures, limited cooling resources, and mass-casualty scenarios (SCFHS, 2023).

Preparedness extends beyond individual training to encompass institutional readiness. Hospitals and EMS agencies are required to maintain heat emergency contingency plans that include adequate stockpiling of cooling equipment, intravenous fluids, and personal protective gear for responders. Annual readiness assessments conducted by the Ministry of Health (MOH) and SCFHS ensure compliance with these requirements. Facilities that demonstrate exceptional preparedness are recognized through national accreditation and quality assurance programs.

Continuous Professional Development (CPD) under SCFHS guidelines ensures that healthcare professionals remain updated with evolving evidence and best practices. Workshops and continuing education courses focus on new technologies such as wearable temperature sensors, mobile command systems, and advanced patient monitoring. Moreover, the SCFHS encourages participation in international conferences and research projects related to environmental and occupational medicine.

Preparedness also includes psychological resilience and occupational safety training for EMS personnel. Exposure to extreme heat can affect responders' physical performance and decision-making abilities. Therefore, the SCFHS incorporates wellness programs and stress management workshops to mitigate fatigue and heat exposure risks among frontline workers.

Simulation-based interagency drills are another cornerstone of preparedness. Joint exercises conducted by the Saudi Red Crescent Authority (SRCA), the Ministry of National Guard Health Affairs (MNGHA), and the Civil Defense Directorate replicate heat wave emergencies and mass-casualty incidents. These exercises enhance coordination, communication, and situational awareness, ensuring that EMS units can operate efficiently during real heat crises.

In conclusion, the SCFHS framework for training and preparedness equips healthcare professionals with the knowledge, skills, and resilience required to manage heat stress effectively. By integrating standardized education, interagency coordination, and continuous evaluation, Saudi Arabia has established a robust model for EMS readiness aligned with global best practices.

Prevention and Public Health Strategies

Preventing heat stress requires an integrated public health approach that combines environmental management, health education, early warning systems, and community-level interventions. In Saudi Arabia, where extreme temperatures are a recurrent public health concern, preventive measures have been institutionalized through collaboration between the Ministry of Health (MOH), the Saudi Red Crescent Authority (SRCA), and the Saudi Commission for Health Specialties (SCFHS). These organizations, supported by international partners such as the World Health Organization (WHO), have developed comprehensive strategies aimed at reducing the incidence and severity of heat-related illnesses.

Public health prevention begins with awareness and education. The MOH conducts annual national campaigns before and during the summer months to educate citizens, outdoor workers, and pilgrims about recognizing early symptoms of heat stress, maintaining hydration, and seeking prompt medical assistance. Educational materials are distributed through television, radio, social media, and mosques, ensuring broad outreach to all demographic groups, including non-Arabic-speaking residents. The SRCA complements these efforts by deploying mobile awareness units that provide on-site education and first aid training at public events and construction sites.

Environmental interventions also play a major role in prevention. Municipal authorities have implemented urban planning strategies to mitigate the heat island effect, such as expanding green spaces, installing shaded pedestrian pathways, and integrating cooling technologies in public areas. During religious gatherings, misting stations, air-conditioned tents, and mobile hydration centers are established in collaboration with MOH and MNGHA to protect pilgrims and field workers from heat exposure (MOH, 2023).

The Saudi government has also developed national heat alert and response systems, aligned with WHO guidelines on climate-related health risks. The National Center for Meteorology (NCM) issues real-time heat warnings based on the Wet Bulb Globe Temperature (WBGT) index, which are shared with healthcare and emergency agencies through digital communication networks. These alerts activate local EMS and hospital preparedness plans, ensuring that medical teams are ready to manage potential surges in heat-related cases.

Occupational safety regulations form another essential component of prevention. The Ministry of Human Resources and Social Development (MHRSD) enforces the 'No Work Under the Sun' policy, which restricts outdoor labor between 12:00 and 3:00 PM during peak summer months. Employers are required to provide shaded rest areas, hydration breaks, and heat safety training to workers in high-risk industries such as construction and oil production.

Heat Awareness Campaigns in Saudi Arabia (2022–2024)
Between 2022 and 2024, the MOH, in collaboration with SRCA and SCFHS, launched several national heat awareness initiatives. These included the 'Stay Hydrated' campaign (2022), 'Beat the Heat' (2023), and the integrated 'Safe Summer' program (2024), all of which emphasized practical guidance for outdoor workers and vulnerable populations. Mobile clinics, awareness booths, and digital applications such as 'Mawid' and 'Sehhaty' were utilized to provide real-time health advice, hydration reminders, and nearby EMS access information. These programs were evaluated positively for increasing public knowledge and reducing emergency heat-related admissions during the Hajj season (SRCA, 2024).

In summary, the prevention of heat stress depends on sustained intersectoral collaboration between government agencies, healthcare providers, and the community. Saudi Arabia's proactive model—combining policy enforcement, technological innovation, and public education—serves as a global example of effective heat stress prevention within an arid climate context. Ongoing investments in research, public awareness, and emergency preparedness will continue to enhance resilience against the escalating impact of global heat exposure.

Case Studies (Saudi + International)

Case studies provide valuable insights into the practical challenges and effectiveness of Emergency Medical Services (EMS) in managing heat stress under real-world conditions. The following examples—one from Saudi Arabia and one from the United States—illustrate best practices, operational challenges, and lessons learned in prehospital and hospital-based heat emergency management.

Case Study 1: Riyadh, Saudi Arabia (2023)

During the summer of 2023, the EMS division of the Ministry of National Guard Health Affairs (MNGHA) responded to a severe heatstroke incident during an outdoor public event in Riyadh. A 42-year-old male security worker collapsed after four hours of exposure to direct sunlight. Upon arrival, the EMS team noted a core temperature of 41.2°C, tachycardia (HR 138 bpm), and confusion. Following the Saudi EMS protocol, field providers initiated immediate active cooling using evaporative techniques and applied ice packs to the axillary and femoral regions. Intravenous isotonic saline was administered, and the patient was transported to King Abdulaziz Medical City within 12 minutes.

Upon arrival at the emergency department, the patient's temperature had decreased to 38.7°C. He was admitted to the intensive care unit (ICU) for monitoring and management of rhabdomyolysis and acute kidney injury, which resolved within 72 hours. This case highlighted the critical importance of early field cooling and rapid coordination between EMS and hospital teams. Following the incident, MNGHA conducted a debriefing session emphasizing enhanced heat surveillance measures for outdoor workers and improved hydration station deployment.

Case Study 2: Phoenix, United States (CDC/NIOSH Report, 2022)

In July 2022, Phoenix, Arizona, experienced one of the most severe heat waves in its recorded history, with temperatures exceeding 46°C for ten consecutive days. According to the CDC's National Institute for Occupational Safety and Health (NIOSH), an outdoor construction worker aged 33 collapsed due to exertional heat stroke during a work shift. EMS arrived within eight minutes and recorded a core temperature of 42°C with altered consciousness. The team implemented cold-water immersion therapy at the scene, a practice widely recommended by NIOSH for exertional heat stroke cases.

The patient's temperature was reduced to 38.5°C within 20 minutes, and he was subsequently transferred to a tertiary care facility for observation. He recovered fully within 48 hours. The post-incident analysis emphasized the effectiveness of early recognition, immediate cooling, and on-site preparedness. The case also reinforced the need for continuous heat safety education among outdoor workers and supervisors.

Comparative Analysis

Both case studies underscore the universal importance of rapid EMS intervention, early cooling, and effective interagency communication. While the Saudi case demonstrates structured coordination between national EMS and hospital networks, the U.S. case highlights the value of decentralized but well-trained EMS units equipped with immersion systems. Together, these examples reinforce that timely, evidence-based prehospital actions can significantly reduce mortality and improve recovery outcomes in heat-related emergencies.

Challenges and Innovations in EMS Response

The management of heat stress presents numerous operational, logistical, and clinical challenges for Emergency Medical Services (EMS). Extreme heat conditions place substantial strain on both responders and healthcare infrastructure, requiring adaptive strategies to maintain effectiveness and safety. This section examines key challenges faced by EMS systems and the innovative solutions that have emerged to address them, particularly within the Saudi Arabian context.

Operational Challenges

One of the foremost challenges in heat stress management is the rapid onset of critical symptoms, which demands swift recognition and intervention. Delays in identifying heat stroke or inadequate cooling measures during transport can result in irreversible organ failure. Field constraints such as limited access to cooling equipment, scarcity of water sources, and high ambient temperatures within ambulances exacerbate these risks.

Additionally, responder safety represents a major concern. EMS personnel working in extreme heat are themselves vulnerable to dehydration, fatigue, and cognitive impairment, which may compromise performance and judgment. The heavy protective gear worn during rescue operations further contributes to thermal strain. Ensuring responder health and hydration during extended field operations is therefore a critical element of EMS management protocols.

Logistical and Environmental Barriers

Logistical coordination during mass gatherings, such as Hajj and Umrah, poses additional complexity. The high density of individuals, language barriers, and the geographical spread of response zones create communication challenges between field teams and command centers. Traffic congestion in urban areas, particularly during heat waves, also delays EMS response times. Furthermore, rural and desert regions often lack adequate cooling infrastructure or immediate access to advanced healthcare facilities, limiting the ability to provide rapid intervention.

Innovations in EMS Response

To overcome these challenges, Saudi Arabia has implemented several innovative strategies integrating technology, training, and infrastructure. One notable advancement is the deployment of mobile cooling units equipped with misting systems and refrigerated compartments for fluid storage. These specialized vehicles, developed in collaboration with the Ministry of National Guard Health Affairs (MNGHA) and the Saudi Red Crescent Authority (SRCA), enhance field management during large-scale events.

Digital transformation has also revolutionized EMS operations. The introduction of the ANAT platform and integrated patient tracking systems allows real-time monitoring of field interventions, temperature data, and patient outcomes. These tools facilitate communication between prehospital teams and hospital emergency departments, reducing treatment delays and improving data accuracy.

Training innovations have played an equally important role. Simulation-based education and virtual reality (VR) training modules developed under the Saudi Commission for Health Specialties (SCFHS) provide paramedics with hands-on experience in managing heat-related emergencies. These programs enhance clinical decision-making under stress and improve team coordination.

Another emerging innovation is the integration of artificial intelligence (AI) and predictive analytics into EMS dispatch systems. By analyzing meteorological data and previous incident trends, AI algorithms can predict high-risk zones and optimize resource allocation before a heat crisis occurs. Pilot projects launched in Riyadh and Makkah in 2024 demonstrated a measurable reduction in EMS response times during extreme heat alerts.

International Innovations

Globally, countries such as Japan and Australia have pioneered wearable temperature sensors for field responders, enabling real-time health monitoring. Similarly, the United States employs drone-assisted delivery of cooling

equipment and fluids to remote or congested sites. These technologies offer promising models that could be adapted to Saudi Arabia's climate and geographical context.

Conclusion

Despite ongoing challenges, the integration of advanced technology, interagency coordination, and continuous training has significantly improved the capacity of EMS systems to manage heat stress. Saudi Arabia's proactive investment in digital infrastructure and responder education represents a benchmark for regional preparedness and innovation. Sustaining these advancements through research, funding, and policy support will ensure long-term resilience against the growing threat of heat-related emergencies.

Discussion

The findings from this research highlight the multifaceted nature of heat stress as a medical and public health emergency, requiring an integrated approach that combines medical, operational, and policy-level interventions. The discussion emphasizes the interconnected roles of Emergency Medical Services (EMS), hospitals, regulatory bodies, and public health authorities in mitigating the burden of heat-related illnesses.

From a clinical standpoint, the research reaffirms that early recognition and immediate intervention are the cornerstones of effective heat stress management. The pathophysiological analysis underscores that once thermoregulatory failure occurs, irreversible cellular and organ damage can ensue within minutes. Therefore, prehospital care remains the most critical determinant of survival. The Saudi EMS model, which prioritizes early field cooling, rapid evacuation, and coordination with hospitals, serves as a leading example of best practice implementation in high-temperature regions.

The epidemiological review reveals that the frequency and severity of heat stress incidents are rising in correlation with global climate trends. Saudi Arabia's unique environmental and demographic context—characterized by extreme heat, rapid urbanization, and large-scale mass gatherings—necessitates ongoing adaptation of EMS and hospital preparedness systems. Comparative data between Saudi Arabia and international case studies (e.g., Phoenix, USA) demonstrate that while infrastructure and technologies may differ, the underlying principles of prevention, rapid response, and coordinated care remain universal.

One key insight derived from this study is the vital role of interagency coordination, particularly between the Ministry of Health (MOH), the Ministry of National Guard Health Affairs (MNGHA), and the Saudi Commission for Health Specialties (SCFHS). The establishment of standardized protocols, shared communication platforms such as ANAT, and joint simulation exercises has collectively enhanced the nation's readiness to respond to heat emergencies. This coordinated model represents a benchmark that can be adapted by other nations facing similar climatic challenges.

Despite these advancements, several challenges persist. Field responders continue to face logistical constraints, including equipment limitations, prolonged exposure to environmental stress, and occasional delays in patient transport during peak congestion periods. In addition, while public awareness campaigns have significantly improved general knowledge about heat safety, sustained behavioral change remains a challenge, particularly among outdoor laborers and at-risk populations.

Innovations in digital health and technology offer promising avenues for future improvement. The integration of artificial intelligence (AI), predictive analytics, and real-time data sharing through platforms such as ANAT and Sehhaty can enhance situational awareness and resource allocation. These technologies, combined with continuous training under SCFHS supervision, are key to sustaining long-term efficiency and resilience in EMS operations.

In the context of global health, Saudi Arabia's model of prevention and emergency management aligns closely with WHO's climate adaptation strategies and the United Nations Sustainable Development Goals (SDG 3 – Good Health and Well-being, and SDG 13 – Climate Action). By investing in preparedness, workforce development, and intersectoral coordination, the country not only strengthens its national health security but also contributes valuable insights to international best practices.

In summary, this discussion emphasizes that combating heat stress requires an integrated systems-based approach that bridges emergency medicine, environmental health, and public policy. The Saudi experience demonstrates that with robust EMS infrastructure, continuous professional education, and evidence-based prevention programs, the impact of heat-related emergencies can be substantially reduced even in the world's hottest climates.

Conclusion

Heat stress remains a critical medical and public health challenge with far-reaching implications for emergency preparedness, clinical management, and occupational safety. This study has demonstrated that timely recognition, immediate cooling, and coordinated response mechanisms are the cornerstones of effective management for heat-related illnesses. The role of Emergency Medical Services (EMS) is central to this framework, serving as the first point of contact and primary determinant of survival in severe cases.

The analysis of Saudi Arabia's healthcare infrastructure and EMS protocols reveals a highly organized and evolving system that effectively integrates prehospital and hospital-based care. Through interagency coordination among the Ministry of Health (MOH), Ministry of National Guard Health Affairs (MNGHA), and the Saudi Commission for Health Specialties (SCFHS), the nation has established a model of excellence in emergency heat response. This approach combines rigorous training, continuous professional development, and real-time communication platforms such as ANAT, enabling seamless transitions from the field to the hospital.

The increasing frequency of extreme heat events, driven by global climate change, underscores the urgent need for sustained investment in public health preparedness. Preventive initiatives—such as national awareness campaigns, occupational safety regulations, and technological innovations—must remain a priority to reduce the overall burden of heat stress. Public education on hydration, acclimatization, and early symptom recognition should be continuously reinforced, particularly among outdoor workers and vulnerable populations.

Globally, Saudi Arabia's experience offers valuable lessons for other nations facing similar climatic and operational challenges. The integration of evidence-based EMS protocols, digital health innovations, and intersectoral collaboration aligns closely with international standards set by the World Health Organization (WHO) and the United Nations Sustainable Development Goals (SDGs). By maintaining its commitment to innovation and resilience, Saudi Arabia continues to strengthen its position as a leader in emergency medical response to environmental health threats.

In conclusion, combating heat stress requires a holistic approach encompassing rapid medical intervention, strategic coordination, and proactive prevention. Empowering EMS providers through continuous education, equipping them with modern technology, and ensuring cohesive communication among healthcare institutions are vital steps toward reducing mortality and enhancing resilience against future heat emergencies. The lessons drawn from this study reaffirm that preparedness, professionalism, and collaboration are the defining pillars of successful response systems in an era of escalating environmental risk.

Conflict of Interest

The authors declare that there is no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethical Considerations

This study did not involve human or animal subjects that required institutional ethical approval.

Author Contributions (CRediT)

All authors contributed to the conceptual development of the study, literature review, manuscript drafting, and critical revision of the final version. All authors approved the final manuscript and agree to be accountable for its contents.

الإجهاد الحراري: حالة طبية حرجة - الدور المحوري لخدمات الطوارئ الطبية في السيطرة على الحالة الملخص

الخلفية: يُعدّ الإجهاد الحراري حالة طبية طارئة تنشأ عندما يعجز الجسم عن التخلص من الحرارة الزائدة، مما يؤدي إلى اضطرابات فسيولوجية قد تهدد في الكشف المبكر، والإدارة الميدانية، والحد من الوفيات (EMS) الحياة. يهدف هذا البحث إلى استعراض الدور المحوري لخدمات الطوارئ الطبية الناتجة عن هذه الحالات في المملكة العربية السعودية، بالاعتماد على التحليل العلمي للأدلة والممارسات الميدانية الحديثة. الهدف: توضيح أهمية خدمات الطوارئ الطبية في السيطرة على حالات الإجهاد الحراري من خلال استعراض البروتوكولات الميدانية، وأدوار التنسيق بين القطاعات الصحية، والعوامل المؤثرة في خفض معدلات الأمراض والوفيات من خلال مراجعة الأدبيات الطبية الدولية والتقارير السعودية (Descriptive–Analytical Approach) المنهجية: تم اعتماد منهج وصفي تحليلي الرسمية الصادرة عن وزارة الصحة، وهيئة الهلال الأحمر السعودي، والهيئة السعودية للتخصصات الصحية، مع تحليل مقارنة للبروتوكولات المطبقة في المملكة وعدد من الدول ذات المناخ الحار النتائج: أظهرت النتائج أن سرعة التبريد الميداني الفعال، والتدريب المستمر لفرق الطوارئ، وتطبيق أنظمة الاتصال الرقمي بين الميدان والمستشفيات

(SCFHS) تُمثّل عوامل رئيسية في تحسين فرص النجاة وتقليل المضاعفات. كما أثبتت البرامج التدريبية المعتمدة من (ANAT مثل منصة أنات) فاعليتها في رفع كفاءة المسعفين وتعزيز الجاهزية الميدانية خلال مواسم الذروة الحرارية مثل الحج والعمرة والاستنتاج: تؤكد الدراسة أن التكامل بين خدمات الطوارئ والمستشفيات والجهات التنظيمية، إلى جانب الاستثمار في التعليم والتقنيات الوقائية، يُعدّ حجر الزاوية في الحد من آثار الإجهاد الحراري. كما توصي بتعزيز حملات التوعية المجتمعية، وتوسيع برامج التدريب، وتحديث بروتوكولات الاستجابة وفق المعايير الدولية

الكلمات المفتاحية: الإجهاد الحراري – ضربة الشمس – خدمات الطوارئ الطبية – التبريد الميداني – الوقاية – المملكة العربية السعودية – الصحة العامة

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