

The Contribution Of Paramedics To The Management Of Heat Stroke And Heat Exhaustion

Khaled Salbi Almorshedy Alotaibi ⁽¹⁾, **Waleed Saud Dakhilallah Al-Mutairi** ⁽²⁾, **Rasheed Eid Oudah Aljameely** ⁽³⁾, **Abdul Karim Munawir Awwadh Al-Mutairi** ⁽⁴⁾, **Abdulmajeed Masad Dakhilallah Almutairi** ⁽⁵⁾, **Saadi Nashir Munashir Alosaimi** ⁽⁶⁾, **Ghazi Monef Alotaibi** ⁽⁷⁾, **Mosa Hammoud Alotaibi** ⁽⁸⁾, **Bandar Barjas Safar Al-Otaibi** ⁽⁹⁾, **Mohammed Saeed Mofareh Alotaibi** ⁽¹⁰⁾

¹Technician Emergency Medical Services, Saudi Red Crescent Authority - Riyadh Region - Afif Sector, Saudi Arabia. srca03610@srca.org.sa

²Technician Emergency Medical Services, Saudi Red Crescent Authority - Riyadh Region - Afif Sector, Saudi Arabia. waleed8844@SRCA.ORG.SA

³Technician Emergency Medical Services, Saudi Red Crescent Authority - Riyadh Region - Afif Sector, Saudi Arabia. aljameely08@gmail.com

⁴Technician Emergency Medical Services, Saudi Red Crescent Authority - Riyadh Region - Afif Sector, Saudi Arabia. krrem5942@gmail.com

⁵Technician Emergency Medical Services, Saudi Red Crescent Authority - Riyadh Region - Afif Sector, Saudi Arabia. all997llaa@gmail.com

⁶Emergency Medicine Technician, Saudi Red Crescent Authority, AL Dawadmi Sector, Riyadh, Kingdom of Saudi Arabia. Saadi55055@gmail.com

⁷Emergency Medicine Technician, Saudi Red Crescent Authority, AL Dawadmi Sector, Riyadh, Kingdom of Saudi Arabia. Ghazi_monef@hotmail.com

⁸EMT, Saudi Red Crescent Authority, Kingdom of Saudi Arabia. MosaHammoud00@gmail.com

⁹Technician Emergency Medical Services, Saudi Red Crescent Authority, Riyadh Region, Nifi Sector, Kingdom of Saudi Arabia. ccvv7004@hotmail.com

¹⁰Technician Emergency Medical Services, Saudi Red Crescent Authority - Riyadh Region - Aljemsh Sector, Saudi Arabia. srca08718@srca.org.sa

Abstract

Heat-related emergencies, particularly heat exhaustion and heat stroke, have become increasingly prevalent worldwide due to climate change effects. Paramedics play a crucial role in the early recognition and management of these conditions, significantly influencing patient outcomes. This review comprehensively examines the contribution of paramedics to the management of heat-related emergencies, focusing on the pathophysiological understanding, importance of prehospital recognition and intervention protocols, and impact on morbidity and mortality mitigation. The epidemiology reveals rising incidence and mortality rates globally, with certain populations at higher risk. Pathophysiologically, heat exhaustion and heat stroke represent a spectrum of severity distinguished by the degree of hyperthermia and organ dysfunction. Cellular and systemic responses, including endothelial injury, cytokine storms, and coagulopathy, contribute to multiorgan failure. Paramedics employ field assessment tools, vital signs interpretation, and thorough scene evaluation to differentiate heat exhaustion from heat stroke. Prehospital management strategies prioritize airway, breathing, and circulation support, rapid cooling techniques, circulatory and renal support, neurological monitoring, and timely transportation decisions. Special considerations are necessary for pediatric and geriatric populations due to their physiological vulnerabilities. Technological innovations, such as wearable sensors and telemedicine, enhance paramedics' assessment and intervention capabilities. However, challenges persist in resource-limited settings, delayed recognition, and mass-casualty events. Addressing these limitations through enhanced training, resource allocation, and ethical decision-making frameworks is crucial for improving prehospital care in heat-related emergencies.

Keywords Paramedics; Heat stroke; Heat exhaustion; Prehospital care; Emergency medical services; Thermoregulation; Cooling techniques; Climate change; Hyperthermia; Early recognition; Rapid intervention; Community education; Telemedicine; Wearable sensors; Public health preparedness.

1. Introduction

Heat-related emergencies, notably heat exhaustion and heat stroke, have become increasingly prevalent worldwide, a trend strongly linked to climate change effects such as rising global temperatures, prolonged heatwaves, and urban heat island phenomena. These environmental shifts have intensified the frequency, duration, and severity of extreme heat events, leading to a growing public health burden with substantial morbidity and mortality risks (O'Connor, 2025).

Pathophysiologically, heat exhaustion and heat stroke represent a spectrum of heat illness severity distinguished primarily by the degree of core body temperature elevation and organ dysfunction. Heat exhaustion is characterized by inadequate thermoregulation leading to excessive dehydration and electrolyte imbalance, yet with preserved central nervous system (CNS) function and core temperatures typically below 40°C. In contrast, heat stroke is a life-threatening condition defined by a core body temperature above 40 to 40.5°C, accompanied by CNS dysfunction including confusion, seizures, or unconsciousness, and often with systemic inflammatory response and multiorgan failure. The distinction is crucial as it guides urgency and intensity of treatment (Garcia et al., 2022).

Early recognition and timely management in the prehospital setting drastically influence patient outcomes, reducing risks for permanent disability or death. Prehospital care aims to rapidly identify heat stroke and initiate cooling procedures to prevent prolonged hyperthermia and subsequent organ damage. Paramedics, as frontline emergency medical responders, are pivotal in this early intervention chain. Their roles encompass assessment utilizing clinical signs and reliable temperature measurement (e.g., rectal thermometry), prompt initiation of rapid cooling techniques such as cold-water immersion or evaporative cooling when water immersion is impractical, and efficient logistics in transport to definitive care. Furthermore, paramedics contribute to community health by educating at-risk populations on heat illness prevention and early symptom recognition (Belval et al., 2018).

This review aims to comprehensively examine the contribution of paramedics to the management of heat-related emergencies, focusing on the pathophysiological understanding distinguishing heat exhaustion from heat stroke, the importance of prehospital recognition and intervention protocols, and the impact on morbidity and mortality mitigation. In light of the escalating incidence associated with climate change, evaluating paramedic practices and identifying opportunities for enhanced prehospital care are of critical relevance for emergency medical services and public health preparedness.

2. Epidemiology of Heat-Related Illnesses

The epidemiology of heat-related illnesses, such as heat stroke and heat exhaustion, reveals significant insights into their global and regional patterns, populations at highest risk, and trends influenced by environmental and societal changes. These illnesses are increasingly prevalent amidst climate change, with rising incidence and mortality worldwide, emphasizing the urgent need for effective ambulance and prehospital response strategies (Kuo et al., 2025).

2.1 Global and Regional Incidence and Mortality Patterns

Heat-related illnesses are a major and growing public health concern, with recent studies indicating a rising trend in both incidence and mortality rates globally. According to recent data, the crude incidence of heat stroke and heat exhaustion in 2024 was 36.4 and 183.9 cases per 100,000 person-years, respectively. The World Health Organization reports that heat stroke is a severe, potentially fatal condition requiring immediate medical intervention, with mortality rates varying across regions depending on healthcare infrastructure and preparedness (Maule et al., 2025).

In Europe, a study estimated an increase of 56% in heat-related deaths during the summer of 2022 compared to previous years, with extremes of mortality observed in older and socioeconomically marginalized populations. In the United States, heat-related mortality rates have also risen, with steep increases particularly since 2018, affecting diverse demographic groups. Similar patterns are seen in Asia, with countries like India experiencing over 31,000 heat-related deaths from 2017 to 2021, reflecting the scale of this public health challenge (Hong et al., 2025).

2.2 Populations at Highest Risk

Certain demographic groups are disproportionately affected by heat-related illnesses. Elderly individuals, particularly those over 65 years, exhibit higher susceptibility due to reduced thermoregulation and higher prevalence of comorbidities. Children under five are also at risk, with their immature thermoregulatory systems making them vulnerable (Clark et al., 2024).

Apart from age, outdoor workers, athletes, and individuals engaged in strenuous activities during hot conditions face elevated risk. Socioeconomic factors compound these risks, with marginalized groups, including racial minorities, urban dwellers experiencing concentrated heat exposure due to urban heat island effects (Schlader et al., 2024).

2.3 Seasonal and Geographical Variability

Seasonal peaks of heat-related illnesses typically occur during the hottest months, with substantial variability across regions depending on climate zones. Urban areas tend to experience higher temperatures, known as the urban heat island effect, amplifying risks during heatwaves. Geographical regions closer to the equator or with arid climates report consistently higher incidence, but climate change has extended heatwaves into temperate zones, increasing exposure durations (Apiratwarakul et al., 2024).

2.4 Trends Linked to Urban Heat, Occupational Exposure, and Environmental Factors

Climate change has intensified heatwaves, contributing to a marked rise in heat-related mortality and morbidity. Urbanization worsens heat exposure, especially for vulnerable populations living in poorly insulated housing or lacking green spaces. Occupational exposure is significant among outdoor workers, especially in agriculture and construction, with heat stress exacerbated by high humidity and pollution levels (Matsee et al., 2023).

2.5 Data from EMS and Prehospital Systems

Emergency Medical Services (EMS) and prehospital systems are vital in managing heat emergencies. Data indicates increasing calls for heat-related illness management, with many cases requiring rapid cooling and supportive care. EMS reports highlight challenges in early recognition of heat stroke, particularly in resource-limited settings, underscoring the importance of public health strategies and training for first responders (Hollander et al., 2021).

3. Pathophysiology of Heat Exhaustion and Heat Stroke

Understanding the pathophysiology of heat exhaustion and heat stroke is foundational to optimizing prehospital care, especially by paramedics, who are often first responders in these medical emergencies. This section explores the mechanisms of thermoregulation and its failure under extreme heat stress, differentiates classic and exertional heat stroke types, elucidates cellular and systemic responses including endothelial injury, cytokine storms, and coagulopathy, and discusses the impacts on critical organ systems. These insights are directly relevant to timely recognition and intervention strategies in the prehospital setting (Morris & Patel, 2023).

3.1 Thermoregulation and Its Breakdown

The human body maintains core temperature tightly, typically around 37°C, through a sophisticated thermoregulatory system involving peripheral and central thermoreceptors that communicate with the hypothalamus. Effector responses include sweating and skin vasodilation to dissipate heat, and vasoconstriction and shivering to conserve or generate heat. This homeostatic balance allows a mere ~1°C core temperature change despite large ambient shifts. Heat dissipation relies heavily on sweat evaporation; however, high humidity (>75%) significantly impairs this mechanism. When environmental heat exceeds skin temperature and evaporative cooling fails, the body's heat loss becomes insufficient, leading to increased core temperature and stress on organ systems (Osilla et al., 2023).

3.2 Distinction Between Classic and Exertional Heat Stroke

Heat stroke manifests mainly in two forms: classic (non-exertional) and exertional. Classic heat stroke typically occurs in vulnerable populations such as the elderly or chronically ill during prolonged environmental heat exposure, developing gradually over days. Patients often present with hot, dry skin due to sweat gland failure. In contrast, exertional heat stroke arises rapidly in otherwise healthy, active individuals performing strenuous physical activity in hot or humid conditions. These patients frequently have moist, sweaty skin. Both types share a core feature of hyperthermia exceeding 40°C along with central nervous system dysfunction, but the underlying triggers and patient profiles differ substantially (Garcia et al., 2022).

3.3 Cellular and Systemic Responses

a. Endothelial Injury

Heat stress directly damages endothelial cells (ECs), which line blood vessels and regulate vascular integrity, permeability, and coagulation. Thermal cytotoxicity, along with systemic inflammatory responses, results in dysfunction and injury to ECs evidenced by increased biomarkers such as ICAM-1, von Willebrand factor, and syndecan-1. This endothelial damage contributes to increased capillary permeability, microvascular thrombosis, and coagulopathy seen in heat stroke patients (Wang et al., 2025).

b. Cytokine Storm and Systemic Inflammation

Heat stroke resembles sepsis in its pathophysiology, characterized by a systemic inflammatory response syndrome (SIRS). Elevated proinflammatory cytokines like interleukin-6 correlate with severity and organ dysfunction. Damage-associated molecular patterns (DAMPs) including HMGB1 and extracellular histones amplify inflammation via activation of toll-like receptors and inflammasomes, perpetuating tissue injury across multiple organs (Yan et al., 2006).

c. Coagulopathy

Heat stroke induces a complex coagulopathy ranging from activation of coagulation cascades to disseminated intravascular coagulation (DIC). Endothelial injury triggers platelet aggregation and microthrombosis, which paradoxically leads to consumptive coagulopathy and bleeding. Biomarkers such as thrombomodulin rise during heat stroke and are linked to severity and mortality risk. Dysfunction of anticoagulant pathways exacerbates microvascular thrombosis and organ ischemia (Iba et al., 2022).

3.4 Impact on Organ Systems

a. Central Nervous System (CNS)

Hyperthermia disrupts cerebral autoregulation, resulting in cerebral hypoperfusion, intracranial hypertension, and ischemia. Clinical manifestations include delirium, seizures, coma, and long-term neurological deficits. The brain is highly sensitive to oxidative stress and free radical damage seen in heat stroke (Yan et al., 2006).

b. Cardiovascular System

Heat stroke imposes significant stress on the heart, including volume depletion from sweating, electrolyte imbalances (hyperkalemia, hypocalcemia), and increased metabolic demands. These factors contribute to arrhythmias, reduced muscle blood flow, and possible rhabdomyolysis. Cardiovascular instability frequently complicates heat stroke and increases mortality risk (Marchand & Gin, 2021).

c. Renal System

Renal injury arises from volume depletion, rhabdomyolysis-related pigment nephropathy, and microvascular thrombosis. Acute kidney injury is common in severe heat stroke and may require renal replacement therapies in intensive care (Wang et al., 2025).

3.5 Pathophysiological Insights for Prehospital Management

Paramedics managing patients with heat stroke should appreciate that thermoregulatory failure rapidly progresses to multiorgan dysfunction driven by cellular injury and systemic inflammation. An immediate goal is aggressive cooling to interrupt the cascade of hyperthermia-induced cytotoxicity. Recognition of CNS impairment guides urgent assessment and treatment. Understanding electrolyte abnormalities and cardiovascular instability informs fluid resuscitation and monitoring strategies. Awareness of coagulopathic tendencies alerts providers to bleeding risks. Overall, pathophysiology underscores the necessity of early, rapid intervention to improve outcomes (Miller et al., 2021).

4. Clinical Features and Differential Diagnosis of Heat Exhaustion and Heat Stroke

Heat exhaustion and heat stroke represent a spectrum of heat-related illnesses distinguished primarily by severity and the presence of central nervous system (CNS) dysfunction. Both conditions arise from exposure to high environmental temperatures, often combined with strenuous physical activity, leading to an inability of the body to adequately dissipate heat (Kenny et al., 2018).

4.1 Definitions and Diagnostic Criteria

Heat Exhaustion is characterized by an elevated core body temperature typically ranging from 37°C to 40°C (98.6°F to 104°F). It occurs when the body's thermoregulatory mechanisms are overwhelmed but still functional enough to prevent CNS impairment. Diagnostic criteria often include symptoms such as heavy sweating, weakness, dizziness, headache, nausea, tachycardia, hypotension, and dehydration while maintaining near-normal mental status (Morris & Patel, 2023).

Heat Stroke is a medical emergency defined by a core body temperature exceeding 40°C (104°F) accompanied by CNS dysfunction, including confusion, agitation, delirium, seizures, or coma. It reflects complete thermoregulatory failure, often manifesting with hot, dry skin (classic heat stroke) or persistent sweating (exertional heat stroke). The diagnosis rests on the presence of both hyperthermia and profound neurological abnormalities. Immediate cooling and supportive care are critical to prevent multisystem organ failure (Morris & Patel, 2023).

4.2 Key Signs and Symptoms

Paramedics identify several hallmark clinical features to differentiate and diagnose heat exhaustion and heat stroke in the field:

- **Core Temperature:** Measured preferably by rectal thermometer; heat exhaustion usually presents with temperatures below 40°C, whereas heat stroke exceeds this threshold.
- **Altered Mental Status:** Absent or mild in heat exhaustion; prominent in heat stroke, including confusion, seizures, or coma.

- **Cardiovascular Signs:** Tachycardia and hypotension are common in both; ongoing dehydration exacerbates hypotension in heat exhaustion.
- **Sweating Pattern:** Profuse sweating in heat exhaustion and exertional heat stroke; anhidrosis (dry skin) more typical of classic heat stroke.
- **Dehydration:** Evident in heat exhaustion due to fluid loss from sweating and inadequate intake.

4.3 Overlapping Conditions and Differential Diagnosis

Paramedics must distinguish heat-related illnesses from other conditions that may mimic symptoms or coexist, including:

- **Sepsis:** Can present with fever, hypotension, and altered mental status, but usually with infectious signs and laboratory markers.
- **Hypoglycemia:** May cause altered mental status and weakness.
- **Central Nervous System Infections:** Such as meningitis or encephalitis; characterized by fever and neurological symptoms.
- **Drug-Induced Hyperthermia:** Conditions like neuroleptic malignant syndrome or serotonin syndrome can cause hyperthermia with CNS changes but are usually associated with specific medication histories (Horseman et al., 2022).

4.4 Field Diagnostic Markers Used by Paramedics

Paramedics employ clinical assessment tools and basic measurements to aid differentiation:

- **Core Temperature Measurement:** The gold standard for diagnosing heat stroke; rectal temperature monitoring is most accurate when feasible.
- **Mental Status Evaluation:** Glasgow Coma Scale or similar scales help quantify CNS impairment.
- **Vital Signs Monitoring:** Heart rate, blood pressure, and respiratory rate evaluation aid in assessing severity.
- **Recognition of Skin Characteristics:** Sweating status (moist vs. dry) guides suspicion towards exertional versus classic heat stroke.
- **Use of Point-of-Care Glucose Testing:** To exclude hypoglycemia in altered patients.

Emerging biomarker research indicates potential future additions to paramedic assessment, such as inflammatory markers (IL-6, CRP), heat shock proteins, and cardiac troponins, which correlate with severity and prognosis, although these are not yet widely accessible in prehospital settings (Palasz et al., 2025).

5. Role of Paramedics in Early Recognition of Heat Stroke and Heat Exhaustion

Paramedics play a crucial role in the early recognition and management of heat-related illnesses, particularly heat stroke and heat exhaustion. Their prompt assessment and decision-making can significantly reduce morbidity and mortality. Let's explore the key components involved in their early recognition process (Wasserman et al., 2023).

5.1 Field Assessment Tools and Protocols

Paramedics utilize EMS-specific protocols designed to identify signs and symptoms of hyperthermia swiftly, even in complex environments. These protocols emphasize recognizing clinical features such as

hyperthermia, altered mental status, and signs of dehydration or collapse to differentiate heat exhaustion from the more severe heat stroke (Miller et al., 2021).

5.2 Vital Signs Interpretation and Rapid Triage Algorithms

Interpretation of vital signs is central to the paramedic's assessment. Key indicators include heart rate, respiratory rate, temperature, and level of consciousness. Tachycardia (>120 bpm), tachypnea (>24 breaths/min), and body temperature above 38.6°C have been validated as sensitive predictors of life-threatening heat illness severity in prehospital settings. Paramedics employ rapid triage scales to prioritize immediate care or transport, using adapted tools such as the National Early Warning Score (NEWS), modified for heat illness cases. These scales assign weighted scores to vital signs and neurological responses to guide triage decisions effectively (Yamaguchi et al., 2023).

5.3 Use of Portable Thermometry and Recognition of Altered Mental States

Portable thermometers are used in the field to estimate patient temperature; however, paramedics must acknowledge the limitations of peripheral temperature measurements (e.g., tympanic, temporal artery), which may underestimate core temperature under hyperthermic conditions. Thus, clinical judgment based on symptoms such as confusion, agitation, seizures, or unconsciousness remains paramount. Recognizing altered mental states signals the need for urgent intervention and has high prognostic value (Hostler et al., 2013).

5.4 Importance of Thorough Scene Assessment and Environmental Context

Paramedics conduct a comprehensive scene assessment, evaluating environmental conditions like ambient temperature, humidity, and potential heat sources. This context helps differentiate heat illness from other causes of altered consciousness and informs the urgency and type of cooling interventions necessary. For example, the presence of heat wave conditions paired with the patient's symptoms heightens suspicion of heat stroke (Abbott et al., 2018).

5.5 Prehospital Triage Scales and Tools

Adaptations of prehospital early warning systems, including the NEWS, assist paramedics in systematically assessing risk and ensuring early hospital notification and expedited care. The NEWS incorporates parameters adjusted for heat-related illness, and higher scores correlate strongly with the need for critical care escalation and mortality risk. Moreover, novel risk scores like the J-ERATO have been proposed to enable quick severity assessments in community and prehospital settings (Hayashida et al., 2018).

6. Prehospital Management by Paramedics in Heat Stroke and Heat Exhaustion

Paramedics play a critical role in the early recognition and management of heat stroke and heat exhaustion during prehospital care. Immediate and appropriate interventions can significantly reduce morbidity and mortality associated with these heat illnesses. We will explore the key components of prehospital management: airway, breathing, circulation (ABCs); temperature reduction; circulatory and renal support; neurological monitoring; pharmacological support; and transportation decisions (Belval et al., 2018).

6.1 Airway, Breathing, and Circulation (ABCs)

Paramedics prioritize airway management in patients exhibiting altered consciousness due to heat stroke. Maintaining a patent airway is crucial as central nervous system dysfunction can compromise airway reflexes. Supplemental oxygen is routinely administered with close monitoring of oxygen saturation to prevent hypoxia. Intravenous access is established promptly to facilitate fluid resuscitation, typically with isotonic saline solutions, to restore circulatory volume and perfusion. These interventions address immediate threats to life and stabilize the patient for further care (Hirschhorn et al., 2021).

6.2 Temperature Reduction Techniques

Rapid cooling is the cornerstone of treatment. Paramedics employ several methods including evaporative cooling, conductive cooling via ice packs or cooling blankets, and immersion techniques when feasible.

- **Cold water immersion (CWI)** is recognized as the gold standard, especially in exertional heat stroke, and achieves rapid cooling (>0.15 °C/min). Portable pools or tubs enable effective whole-body immersion where resources permit (Young et al., 2023).
- **Evaporative cooling**, achieved by spraying mist while fanning, is preferred in elderly, children, or patients with comorbidities to minimize shivering and cardiac stress.
- **Applying ice packs** to the neck, axillae, and groin aids localized cooling.
- **Cold intravenous fluids** can contribute to core temperature reduction but are supplementary and less effective than surface cooling (McDermott & Atkins, 2023).

Paramedics continuously monitor core temperature using rectal thermometry when possible, avoiding overcooling to prevent hypothermia and shivering which may generate heat counterproductively (Hirschhorn et al., 2021).

6.3 Circulatory and Renal Support

Fluid therapy aims to restore intravascular volume using isotonic saline to avoid hyponatremia or hypotonic complications. Paramedics assess hydration status and observe urine output if feasible, as monitoring renal perfusion may indicate evolving organ dysfunction. Early recognition of shock and rhabdomyolysis guides escalation of care and rapid transport. Prompt intravenous fluids may reduce complications secondary to hypovolemia and renal injury (Belval et al., 2018).

6.4 Neurological Monitoring

Heat stroke often impairs neurological function. Glasgow Coma Scale (GCS) scores are routinely obtained and reassessed to detect changes in consciousness. Seizure precautions are implemented, including preparing for rapid airway protection and immediate transport if seizures occur or if CNS dysfunction deteriorates. Continuous neurological evaluation guides urgency of transport and interventions (Belval et al., 2018).

6.5 Pharmacological Support

Pharmacologic interventions are limited in prehospital heat stroke management:

- **Antipyretics (e.g., acetaminophen, aspirin) are not effective** as hyperthermia results from failure of thermoregulatory mechanisms, not fever pathways, and thus are avoided (Walter & Steel, 2018).
- **Benzodiazepines** are indicated for seizure control or severe agitation accompanying heat stroke. They assist in muscle relaxation and may help reduce metabolic heat production during shivering triggered by cooling (Patel et al., 2023).
- Sedation is cautiously used with attention to airway protection (Patel et al., 2023).

6.6 Transportation Decisions

Paramedics decide transport urgency based on severity. Severe heat stroke with CNS impairment mandates urgent transport post-initiation of cooling, following the principle of "cool first, transport second". Mild cases or heat exhaustion may be managed initially on scene if stable, with close monitoring (Cong et al., 2025).

Communication with receiving emergency departments is vital to prepare for advanced care, especially during mass casualty or heatwave events where resource coordination is essential. Prehospital providers should alert hospitals early to ensure readiness for ongoing cooling, monitoring, and organ support (Belval et al., 2018).

7. Special Considerations in Pediatric and Geriatric Populations

7.1 Physiological Vulnerability Due to Limited Thermoregulation

In pediatric patients, particularly those younger than 12 years, thermoregulatory mechanisms are not fully developed. Children have a higher surface area-to-body mass ratio, leading to rapid heat gain and loss, which makes them more susceptible to heat stroke and exhaustion. Their sweat glands and ability to dissipate heat efficiently are limited, increasing risk for rapid core temperature elevation. For elderly patients, aging impairs thermoregulation via decreased sweat gland function, reduced cardiovascular adaptability, and a diminished thirst response. These changes reduce heat dissipation capacity and the ability to maintain homeostasis during heat stress, often leading to exacerbated heat-related morbidity and mortality. Moreover, chronic diseases common in the elderly (cardiovascular, diabetes) and the use of certain medications (diuretics, beta blockers, anticholinergics) further impair heat tolerance (Smith, 2019).

7.2 Adaptation of Prehospital Protocols

Paramedics must adapt protocols to account for the rapid cooling needs and monitoring challenges in these populations. For pediatric patients, continuous core temperature monitoring via rectal thermometry is recommended since peripheral methods (temporal, tympanic) may be unreliable. Active cooling methods like evaporative cooling (removing clothing, applying cool mist, fanning) are preferred for children under 12 years due to risks of overcooling with immersion. Careful titration of cooling to avoid hypothermia is essential. In elderly patients, prehospital care includes aggressive cooling while monitoring hemodynamic status and considering comorbidities. EMS protocols should include use of appropriate medication dosing (e.g., via pediatric dosing cards) and vigilant cardiovascular monitoring due to altered physiology. Paramedics should anticipate complications such as seizures or cardiac arrhythmias during cooling and be prepared for advanced airway management (Miller et al., 2021).

7.3 Common Confounding Factors in Elderly Patients

Elderly patients often present with confounding factors that complicate heat stroke diagnosis and management. Comorbidities such as cardiovascular disease, diabetes, and cognitive impairment reduce physiological reserves and may mask typical heat illness symptoms. Medications including diuretics, antihistamines, beta blockers, antipsychotics, and antidepressants alter thermoregulation or hydration status, increasing vulnerability and complicating clinical presentation. Polypharmacy and reduced mobility also affect outcomes. These factors necessitate paramedics' heightened vigilance, tailored assessment, and management to include medication review and anticipation of atypical presentations (Layton et al., 2020).

7.4 Prevention and Community Education in High-Risk Groups

Paramedics' role extends beyond acute care to community education and prevention, especially for high-risk pediatric and elderly groups. Community paramedicine programs can conduct welfare checks during heat waves, provide hydration guidance, encourage use of cooling resources, and educate on early recognition of heat illness signs. Tailored teaching on risks associated with medications and chronic conditions is essential for elderly patients and caregivers. Public health campaigns targeting parents, caregivers, and elderly communities improve heat literacy and behaviors that reduce heat-related emergencies. Evidence shows community education reduces hospital visit rates and improves heat illness management outcomes (Razzak et al., 2022).

8. Technological and Diagnostic Innovations

The management of heat stroke and heat exhaustion in prehospital settings has seen significant advancements due to emerging technological and diagnostic innovations. These innovations enhance paramedics' ability to rapidly assess, monitor, and intervene effectively during heat emergencies.

8.1 Portable Body Temperature Monitors and Wearable Sensors

Paramedics increasingly utilize portable and wearable devices to continuously monitor patients' physiological parameters, notably core body temperature a critical metric in heat-related illnesses. Recent developments in wearable sensors allow non-invasive, continuous monitoring of deep body temperature using technologies such as the dual-heat-flux method. These devices integrate multiple sensors, including temperature, heart rate, and accelerometers, providing real-time physiological and environmental data via Bluetooth or cloud platforms. This enables paramedics to detect early signs of heat strain and intervene promptly to prevent progression to severe heat stroke. Studies validate the accuracy and feasibility of such Internet of Things (IoT) based systems for heatstroke prevention in high-temperature environments, which can alert both patients and responders to escalating risk (Yeh et al., 2021).

8.2 Infrared Thermometry Accuracy and Limitations in Field Conditions

Infrared (IR) thermometry is widely used by paramedics for rapid, non-contact temperature screening during heat emergencies due to its convenience and speed. However, IR thermometers primarily measure surface skin temperature, which may not accurately reflect core body temperature, especially under variable environmental conditions such as direct sunlight, humidity, and air movement. Reflective surfaces and improper sensor positioning can further affect accuracy. Calibration and proper usage techniques, including maintaining optimal distance-to-spot ratios and adjusting emissivity settings, are essential to improve measurement reliability. Despite these limitations, IR thermometry remains an invaluable tool in the field when used with an understanding of its constraints (Holder et al., 2024).

8.3 Use of Telemedicine and Remote Physician Consultation

The integration of telemedicine into prehospital care has transformed paramedics' capacity to manage heat-related emergencies. Through tele-EMS systems, paramedics can perform remote consultations with emergency physicians in real-time, enabling expert guidance on diagnosis, treatment decisions, and patient disposition without delay. This support is crucial in complex cases of heat stroke and exhaustion, where rapid cooling and advanced interventions may be required. Teleconsultations have been shown to improve the structural and procedural quality of EMS responses, increase onsite physician availability virtually, and reduce the need for unnecessary hospital transports. Such telehealth applications enhance paramedics' confidence and care quality in diverse prehospital settings (Su et al., 2025).

8.4 Integration of Real-Time Environmental Data in Ambulance Dispatch Systems

Modern EMS dispatch systems incorporate real-time environmental data, including ambient temperature, humidity, and heatwave alerts, to optimize resource allocation and preparedness for heat emergencies. By analyzing geospatial heat exposure and forecasting heatwave intensity, dispatcher systems can proactively prioritize ambulance dispatches to vulnerable populations at risk of heat stroke or exhaustion. This integration enables EMS systems to respond more efficiently during periods of extreme heat, minimizing response times and improving patient outcomes. Research highlights a dose-response relationship between heatwave severity and ambulance dispatch demand, supporting the value of real-time environmental data in EMS operational decision-making (Guo et al., 2025).

9. Challenges and Limitations in Prehospital Management

The prehospital management of heat stroke and heat exhaustion by paramedics faces numerous challenges and inherent limitations, particularly pronounced in resource-limited, rural, and mass casualty settings.

These obstacles can significantly impact the timely and effective care delivery crucial for reducing morbidity and mortality in heat-related emergencies.

9.1 Barriers in Resource-Limited or Rural Settings

In rural or resource-constrained areas, delayed emergency medical services (EMS) response times pose a critical barrier to effective prehospital care of heat illnesses. Patients in community or rural settings often experience prolonged intervals before professional medical assistance arrives, contributing to worse outcomes compared to medically supervised environments such as athletic events or military settings where immediate intervention is available. Ambulance services may lack specialized cooling equipment or protocols for rapid heat illness recognition and treatment, compounding challenges in these regions. Additionally, geographic isolation and limited healthcare infrastructure restrict access to advanced cooling therapies and educational outreach for early heat illness identification (Ahn et al., 2025).

9.2 Limitations of Field Equipment and Environmental Hazards

Paramedics in the field confront significant limitations related to the availability and practical usability of cooling apparatus. Space constraints in ambulances may preclude carrying ideal cooling devices such as cold water immersion tubs, which are considered the gold standard for rapid cooling. Alternative methods such as evaporative cooling with misting and fanning or cold saline infusion have logistical limitations regarding efficacy and availability. Environmental hazards like extreme heat, humidity, and terrain challenges further restrict paramedics' ability to implement effective cooling measures safely and promptly. Moreover, personal protective equipment (PPE) required for other hazards may increase heat burden on responders, reducing their operational tolerance and complicating patient handling in hot conditions (Leyk et al., 2019).

9.3 Delayed Recognition Due to Atypical Presentation

Recognition of heat stroke and heat exhaustion in the prehospital setting can be delayed because symptom presentation is often atypical, especially in vulnerable populations such as the elderly, comorbid patients, or those acclimated poorly to heat. Symptoms like altered mental status, dehydration signs, and muscle cramps may overlap with other medical conditions, complicating prompt diagnosis. Delays in recognizing heat illness lead directly to prolonged hyperthermia and worsen patient outcomes. Enhanced training for EMS personnel on varied clinical presentations, greater use of objective temperature measurement, and dispatcher-assisted first aid instructions are strategies recommended to reduce diagnostic delays (Cong et al., 2025).

9.4 Ethical and Logistical Considerations During Mass-Casualty Heat Events

Mass-casualty incidents (MASCAL) induced by extreme heat waves introduce unique ethical and logistical challenges in prehospital heat illness management. Scarcity of resources, including personnel, cooling devices, and transport capabilities, forces difficult triage decisions under crisis conditions. Ethical principles such as distributive justice, fairness, and duty to maximize lives saved guide these decisions but require robust disaster preparedness plans inclusive of ethical frameworks. Logistical considerations include coordination among multiple responding agencies, rapid establishment of cooling stations, and ensuring equitable care access across affected populations. Transparency, community engagement, and ethically sound decision-making protocols are essential to maintain trust and optimize outcomes during these events (Leider et al., 2017).

Conclusion

Heat-related illnesses, particularly heat exhaustion and heat stroke, represent an escalating global health threat intensified by climate change and urbanization. Paramedics serve as the critical first line of defense in reducing morbidity and mortality through early recognition, immediate intervention, and efficient patient

transport. Their expertise in rapid assessment, temperature control, airway management, and circulatory support significantly improves patient outcomes. Furthermore, emerging technologies such as wearable temperature monitors, telemedicine, and data-integrated EMS systems are enhancing prehospital efficiency and decision-making. Despite existing barriers such as equipment limitations, delayed recognition, and logistical constraints, ongoing training, protocol optimization, and resource investment are vital for strengthening paramedic preparedness. Ultimately, empowering paramedics through evidence-based practice, innovation, and community education will remain central to mitigating the growing impact of heat-related emergencies worldwide.

References

1. Abbott, T. E. F., Cron, N., Vaid, N., Ip, D., Torrance, H. D. T., & Emmanuel, J. (2018). Pre-hospital National Early Warning Score (NEWS) is associated with in-hospital mortality and critical care unit admission: A cohort study. *Annals of Medicine and Surgery*, 27, 17–21. <https://doi.org/10.1016/j.amsu.2018.01.006>
2. Ahn, M., Keith, L., & Brown, H. E. (2025). Rural heat health disparities: Evidence from the U.S. National Emergency Medical Services Information System (NEMSIS). *The Journal of Climate Change and Health*, 22, 100432. <https://doi.org/10.1016/j.joclim.2025.100432>
3. Apiratwarakul, K., Cheung, L. W., Pearkao, C., & Ienghong, K. (2024). The Impact of Global Warming on the Rise in Heat-Related Illnesses in Emergency Medical Services. *Journal of Multidisciplinary Healthcare*, 17, 5211–5216. <https://doi.org/10.2147/JMDH.S501721>
4. Belval, L. N., Casa, D. J., Adams, W. M., Chiampas, G. T., Holschen, J. C., Hosokawa, Y., Jardine, J., Kane, S. F., Labotz, M., Lemieux, R. S., McClaine, K. B., Nye, N. S., O'Connor, F. G., Prine, B., Raukar, N. P., Smith, M. S., & Stearns, R. L. (2018). Consensus Statement- Prehospital Care of Exertional Heat Stroke. *Prehospital Emergency Care*, 22(3), 392–397. <https://doi.org/10.1080/10903127.2017.1392666>
5. Clark, A., Grineski, S., Curtis, D. S., & Cheung, E. S. L. (2024). Identifying groups at-risk to extreme heat: Intersections of age, race/ethnicity, and socioeconomic status. *Environment International*, 191, 108988. <https://doi.org/10.1016/j.envint.2024.108988>
6. Cong, S., Zheng, G., Liang, X., Gui, J., Zhang, H., & Wang, J. (2025). Pre-hospital cooling in community-acquired heat stroke (CAHS): Evidence, challenges, and strategies. *European Journal of Medical Research*, 30(1), 472. <https://doi.org/10.1186/s40001-025-02628-x>
7. Garcia, C. K., Renteria, L. I., Leite-Santos, G., Leon, L. R., & Laitano, O. (2022). Exertional heat stroke: Pathophysiology and risk factors. *BMJ Medicine*, 1(1). <https://doi.org/10.1136/bmjmed-2022-000239>
8. Guo, Q., Madaniyazi, L., Nomura, S., Chen, K., & Hashizume, M. (2025). Population aging exacerbates heat stroke-related ambulance transportations in Japan. *Environment International*, 199, 109506. <https://doi.org/10.1016/j.envint.2025.109506>
9. Hayashida, K., Kondo, Y., Hifumi, T., Shimazaki, J., Oda, Y., Shiraishi, S., Fukuda, T., Sasaki, J., & Shimizu, K. (2018). A novel early risk assessment tool for detecting clinical outcomes in patients with heat-related illness (J-ERATO score): Development and validation in independent cohorts in Japan. *PLOS ONE*, 13(5), e0197032. <https://doi.org/10.1371/journal.pone.0197032>
10. Hirschhorn, R., DadeMatthews, O., & Sefton, J. (2021). Exertional Heat Stroke Knowledge and Management among Emergency Medical Service Providers. *International Journal of Environmental Research and Public Health*, 18(9), 5016. <https://doi.org/10.3390/ijerph18095016>
11. Holder, T., Hooper, F. S. W., Yates, D., Tse, Z., Patil, S., Moussa, A., Batten, L., Radhakrishnan, V., Allison, M., Hewitt, C., Keding, A., Forshaw, G., & Jayagopal, V. (2024). Clinical accuracy of infrared temperature measurement devices: A comparison against non-invasive core-body temperature. *Clinical Medicine*, 23(2), 157–163. <https://doi.org/10.7861/clinmed.2022-0252>
12. Hollander, K., Klöwer, M., Richardson, A., Navarro, L., Racinais, S., Scheer, V., Murray, A., Branco, P., Timpka, T., Junge, A., & Edouard, P. (2021). Apparent temperature and heat-related illnesses during

- international athletic championships: A prospective cohort study. *Scandinavian Journal of Medicine & Science in Sports*, 31(11), 2092–2102. <https://doi.org/10.1111/sms.14029>
13. Hong, Y.-R., Dalisay, F. S., & Xie, Z. (2025). Trends in Rates of Heat-Related Deaths Across Population Groups in the United States, 2000-2023. *Public Health Reports* (Washington, D.C.: 1974), 140(4), 294–299. <https://doi.org/10.1177/00333549251342904>
14. Horseman, M., Panahi, L., Udeani, G., Tenpas, A. S., Verduzco Jr., R., Patel, P. H., Bazan, D. Z., Mora, A., Samuel, N., Mingle, A.-C., Leon, L. R., Varon, J., & Surani, S. (2022). Drug-Induced Hyperthermia Review. *Cureus*. <https://doi.org/10.7759/cureus.27278>
15. Hostler, D., Rittenberger, J. C., Schillo, G., & Lawery, M. (2013). Identification and Treatment of Heat Stroke in the Prehospital Setting. *Wilderness & Environmental Medicine*, 24(2), 175–177. <https://doi.org/10.1016/j.wem.2012.10.006>
16. Iba, T., Connors, J. M., Levi, M., & Levy, J. H. (2022). Heatstroke-induced coagulopathy: Biomarkers, mechanistic insights, and patient management. *EClinicalMedicine*, 44, 101276. <https://doi.org/10.1016/j.eclinm.2022.101276>
17. Kenny, G. P., Wilson, T. E., Flouris, A. D., & Fujii, N. (2018). Heat exhaustion. *Handbook of Clinical Neurology*, 157, 505–529. <https://doi.org/10.1016/B978-0-444-64074-1.00031-8>
18. Kuo, W.-Y., Huang, C.-C., Chen, C.-A., Ho, C.-H., Hsu, C.-C., Lin, H.-J., Su, S.-B., Wang, J.-J., & Guo, H.-R. (2025). Epidemiological characteristics of heat-related illness: A nationwide study in Taiwan. *BMC Public Health*, 25(1), 3063. <https://doi.org/10.1186/s12889-025-24344-1>
19. Layton, J. B., Li, W., Yuan, J., Gilman, J. P., Horton, D. B., & Setoguchi, S. (2020). Heatwaves, medications, and heat-related hospitalization in older Medicare beneficiaries with chronic conditions. *PLoS ONE*, 15(12), e0243665. <https://doi.org/10.1371/journal.pone.0243665>
20. Leider, J. P., DeBruin, D., Reynolds, N., Koch, A., & Seaberg, J. (2017). Ethical Guidance for Disaster Response, Specifically Around Crisis Standards of Care: A Systematic Review. *American Journal of Public Health*, 107(9), e1–e9. <https://doi.org/10.2105/AJPH.2017.303882>
21. Leyk, D., Hoitz, J., Becker, C., Jochen Glitz, K., Nestler, K., & Piekarski, C. (2019). Health Risks and Interventions in Exertional Heat Stress. *Deutsches Ärzteblatt International*, 116(31–32), 537–544. <https://doi.org/10.3238/arztebl.2019.0537>
22. Marchand, M., & Gin, K. (2021). The Cardiovascular System in Heat Stroke. *CJC Open*, 4(2), 158–163. <https://doi.org/10.1016/j.cjco.2021.10.002>
23. Matsee, W., Charoensakulchai, S., & Khatib, A. N. (2023). Heat-related illnesses are an increasing threat for travellers to hot climate destinations. *Journal of Travel Medicine*, 30(4), taad072. <https://doi.org/10.1093/jtm/taad072>
24. Maule, A. L., Kotas, K. S., Scatliffe-Carrion, K. D., & Ambrose, J. F. (2025). Heat exhaustion and heat stroke among active component members of the U.S. Armed Forces, 2020-2024. *MSMR*, 32(6), 4–10.
25. McDermott, B. P., & Atkins, W. C. (2023). Whole-body cooling effectiveness of cold intravenous saline following exercise hyperthermia: A randomized trial. *The American Journal of Emergency Medicine*, 72, 188–192. <https://doi.org/10.1016/j.ajem.2023.07.053>
26. Miller, K. C., Casa, D. J., Adams, W. M., Hosokawa, Y., Cates, J., Emrich, C., Fitzpatrick, T., Hopper, M., Jardine, J. F., LaBotz, M., Lopez, R. M., O'Connor, F., & Smith, M. S. (2021). Roundtable on Preseason Heat Safety in Secondary School Athletics: Prehospital Care of Patients With Exertional Heat Stroke. *Journal of Athletic Training*, 56(4), 372–382. <https://doi.org/10.4085/1062-6050-0173.20>
27. Morris, A., & Patel, G. (2023). Heat Stroke. In *StatPearls* [Internet]. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK537135/>
28. O'Connor, F. G. (2025). Heat-Related Illnesses. *Annals of Internal Medicine*, 178(7), ITC97–ITC112. <https://doi.org/10.7326/ANNALS-25-01958>
29. Osilla, E. V., Marsidi, J. L., Shumway, K. R., & Sharma, S. (2023). Physiology, Temperature Regulation. In *StatPearls* [Internet]. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK507838/>

30. Palasz, J., Farooqi, W., Musharraf, M. B., Rippon, B., Jedlicka, C., & Razzak, J. (2025). Diagnostic Biomarkers for Heat Stroke and Heat Exhaustion: A Scoping Review. *Disaster Medicine and Public Health Preparedness*, 19, e153. <https://doi.org/10.1017/dmp.2025.10069>
31. Patel, J., Boyer, N., Mensah, K., Haider, S., Gibson, O., Martin, D., & Walter, E. (2023). Critical illness aspects of heatstroke: A hot topic. *Journal of the Intensive Care Society*, 24(2), 206–214. <https://doi.org/10.1177/17511437221148922>
32. Razzak, J. A., Agrawal, P., Chand, Z., Quraishy, S., Ghaffar, A., & Hyder, A. A. (2022). Impact of community education on heat-related health outcomes and heat literacy among low-income communities in Karachi, Pakistan: A randomised controlled trial. *BMJ Global Health*, 7(1), e006845. <https://doi.org/10.1136/bmjgh-2021-006845>
33. Schlader, Z. J., Tourula, E., & Lignier, M. J. (2024). Protecting vulnerable populations in extreme heat – a growing and pervasive health challenge. *eBioMedicine*, 109, 105448. <https://doi.org/10.1016/j.ebiom.2024.105448>
34. Smith, C. J. (2019). Pediatric Thermoregulation: Considerations in the Face of Global Climate Change. *Nutrients*, 11(9), 2010. <https://doi.org/10.3390/nu11092010>
35. Su, J. S., Shanes, A., & Quinn, E. (2025). EMS Telemedicine in the Prehospital Setting. In StatPearls [Internet]. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK597357/>
36. Walter, E., & Steel, K. (2018). Management of exertional heat stroke: A practical update for primary care physicians. *The British Journal of General Practice*, 68(668), 153–154. <https://doi.org/10.3399/bjgp18X695273>
37. Wang, S., Zhang, X., Zhang, Y., Wu, N., Bo, L., & Wang, M. (2025). The pathogenesis and therapeutic strategies of heat stroke-induced endothelial injury. *Frontiers in Cell and Developmental Biology*, 13. <https://doi.org/10.3389/fcell.2025.1569346>
38. Wasserman, D. D., Thurman, J., & Healy, M. (2023). EMS Methods to Cool a Patient in the Field. In StatPearls [Internet]. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK459303/>
39. Yamaguchi, J., Kinoshita, K., & Takeyama, M. (2023). An Easy-to-Use Prehospital Indicator to Determine the Severity of Suspected Heat-Related Illness: An Observational Study in the Tokyo Metropolitan Area. *Diagnostics*, 13(16), 2683. <https://doi.org/10.3390/diagnostics13162683>
40. Yan, Y.-E., Zhao, Y.-Q., Wang, H., & Fan, M. (2006). Pathophysiological factors underlying heatstroke. *Medical Hypotheses*, 67(3), 609–617. <https://doi.org/10.1016/j.mehy.2005.12.048>
41. Yeh, C.-Y., Chung, Y.-T., Chuang, K.-T., Shu, Y.-C., Kao, H.-Y., Chen, P.-L., Ko, W.-C., & Ko, N.-Y. (2021). An Innovative Wearable Device For Monitoring Continuous Body Surface Temperature (HEARThermo): Instrument Validation Study. *JMIR mHealth and uHealth*, 9(2), e19210. <https://doi.org/10.2196/19210>
42. Young, D., Everitt, B., Fine, B., & Miramontes, D. (2023). Immersive Cooling in the Prehospital Setting for Heat Stroke: A Case Report. *Prehospital Emergency Care*, 27(6), 838–840. <https://doi.org/10.1080/10903127.2023.2201515>