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Prehospital Management of Heat-Related Illness in a Changing Climate: A Review of Adaptation Strategies and Vulnerable Populations

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Abstract: Climate change is driving an increase in the frequency and intensity of extreme heat events, leading to a rising incidence of heat-related illnesses (HRI) and placing significant strain on healthcare systems. The prehospital phase, managed by Emergency Medical Services (EMS), is a critical window for intervention, as rapid cooling is the primary determinant of survival for severe HRI like heat stroke. This scoping review synthesizes evidence on the efficacy of prehospital HRI management, the identification of vulnerable populations, and system-level adaptation strategies. Findings confirm that cold water immersion is the most effective cooling method for exertional heat stroke, while evaporative cooling is the most feasible and widely applicable technique across diverse settings. The burden of HRI disproportionately affects vulnerable groups, including the elderly, outdoor laborers, and socially marginalized populations, due to physiological, environmental, and socioeconomic factors. Effective management requires not only evidence-based clinical protocols but also the integration of EMS with public health heat warning systems, community paramedicine, and proactive, equitable outreach. Significant barriers to implementation include technological limitations, resource constraints, and fragmented inter-agency coordination. Future efforts must focus on standardizing protocols, enhancing training, and addressing research gaps through robust studies on cooling efficacy, cost-effectiveness of community interventions, and the long-term impact of adaptive strategies on patient outcomes.

Keywords: Heat-Related Illness, Prehospital Care, Emergency Medical Services, Climate Change, Vulnerable Populations.

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1. Introduction

1.1. The Escalating Threat: Climate Change and Extreme Heat Events

Climate change represents one of the most significant global health threats of the 21st century, with extreme heat events (EHEs) increasing in frequency, intensity, and duration (IPCC, 2022). The past decade has been the warmest on record, and projections from the Intergovernmental Panel on Climate Change (IPCC, 2021) indicate that average global temperatures are projected to rise by 1.5°C above pre-industrial levels as early as 2030, leading to a further increase in the frequency and intensity of heatwaves. This escalating environmental reality is directly translating into a surge in heat-related illnesses (HRI), placing an unprecedented strain on healthcare systems. The health impacts are already evident; the World Health Organization (2021) estimates that climate change will cause approximately 250,000 additional deaths per year between 2030 and 2050, with heat stress being a significant contributor. EHEs now claim more lives annually in many countries than all other weather-related disasters combined (Vicedo-Cabrera et al., 2021). These dire consequences disproportionately affect vulnerable populations, including the elderly, individuals with pre-existing health conditions, and those in low-income communities (Huang et al., 2020; Vardoulakis et al., 2014), demanding a critical re-evaluation of public health and emergency response preparedness.

1.2. Spectrum and Pathophysiology of Heat-Related Illness (HRI)

Heat-related illness encompasses a clinical spectrum ranging from mild conditions such as heat edema and heat cramps to life-threatening heat stroke (Lipman et al., 2019; Nielsen et al., 2021). The pathophysiology of HRI is rooted in the body's failure to thermoregulate effectively. Under heat stress, the primary cooling mechanism is sweating and its subsequent evaporation. When this system is overwhelmed—due to excessive heat production, inadequate heat loss, or a combination of both—core body temperature rises precipitously (Bouchama & Knochel, 2002). This leads to a cascade of physiological insults, including a systemic inflammatory response, endothelial damage, and disseminated

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intravascular coagulation, which can result in dehydration, electrolyte imbalance, and ultimately, multi-organ failure (Epstein & Yanovich, 2019; Luber & Prudent, 2009). Heat stroke, the most severe form, is defined by a core body temperature typically >40°C (104°F) and central nervous system dysfunction (e.g., altered mental status, seizures, or coma). The distinction between classic (non-exertional) heat stroke, which occurs during seasonal heatwaves and predominantly affects the elderly and chronically ill, and exertional heat stroke, which affects otherwise healthy individuals during strenuous physical activity, is critical for understanding at-risk populations (Morris & Patel, 2021).

1.3. The Critical Role of Prehospital Care in the HRI Continuum

For patients with severe HRI, particularly heat stroke, the timeliness of cooling is the single most important determinant of survival. The concept of the "golden hour" is paramount, with mortality increasing significantly for every minute that core temperature remains elevated (Gaudio & Grissom, 2016). As the first medical responders, Emergency Medical Services (EMS) personnel are positioned at the critical juncture where definitive intervention must begin (Wang et al., 2020). The prehospital phase is not merely one of transport; it is a therapeutic window where rapid assessment, immediate initiation of cooling, and appropriate fluid management can dramatically alter the clinical trajectory (Hosokawa et al., 2020; Bouchama et al., 2007). Prehospital providers must operate in often chaotic and environmentally challenging conditions to differentiate HRI from other causes of altered mental status, initiate life-saving cooling protocols, and make crucial triage decisions. The effectiveness of this initial response directly impacts downstream outcomes, including the incidence of long-term neurological sequelae and overall mortality (Bouchama et al., 2022), making EMS training and preparedness essential.

1.4. Rationale and Objectives of the Review

Despite the clear and growing threat posed by EHEs, the evidence base guiding prehospital management of HRI is fragmented. While clinical guidelines for in-hospital management exist, their translation to the unique constraints of the prehospital environment—with limited resources, diagnostic tools, and environmental control—remains challenging (Lipman et al., 2019). A comprehensive synthesis of current evidence is urgently needed to identify best practices, highlight gaps in knowledge, and guide the development of robust, climate-resilient prehospital care systems. Therefore, this scoping review aims to systematically map the existing literature to address the following objectives:

1. To synthesize the current evidence on the efficacy of prehospital cooling modalities and management strategies for HRI.
2. To identify and characterize vulnerable populations at heightened risk for severe HRI and prehospital complications.
3. To explore and evaluate existing adaptation strategies and system-level interventions designed to enhance EMS preparedness and response to heatwaves.
4. To delineate the key challenges and barriers to effective prehospital HRI care and identify priorities for future research, policy, and clinical practice.

2. Methods

2.1. Review Design and Protocol

This study was conducted as a scoping review to systematically map the breadth of available literature on prehospital management of heat-related illness (HRI) within the context of a changing climate. The scoping review methodology was selected as it is particularly suited to examining emerging areas of research, clarifying key concepts, and identifying gaps in the evidence base where a more precise systematic review is not yet feasible (Peters et al., 2020). The review protocol was developed *a priori* and guided by the methodological framework proposed by Arksey and O'Malley (2005) and the subsequent enhancements from the Joanna Briggs Institute (JBI). The process adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist to ensure comprehensive and transparent reporting (Tricco et al., 2018).

2.2. Search Strategy and Information Sources

A comprehensive and systematic search strategy was designed and executed to identify both published and grey literature. The search was applied to several major electronic bibliographic databases, including PubMed/MEDLINE, EMBASE, CINAHL, Web of Science, and Scopus. To capture relevant policy documents and implementation reports, targeted searches were also conducted in Google Scholar and the websites of key organizations such as the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and relevant emergency medical services (EMS) professional bodies. Boolean operators (AND, OR) were used to combine these concepts. The search was limited to literature published in English from January 2000 to September 2023 to capture modern EMS practices and contemporary climate data. An example of the full search strategy for PubMed is provided in Appendix A.

2.3. Eligibility Criteria

The study selection criteria were defined using the PCC (Population, Concept, Context) framework recommended for scoping reviews (JBI, 2020).

- The review focused on studies involving prehospital patients of any age with suspected or confirmed HRI, as well as the EMS providers (e.g., paramedics, emergency medical technicians) who manage them.
- The central concept was the prehospital management of HRI, encompassing clinical interventions (e.g., cooling techniques, fluid resuscitation), clinical decision-making, and system-level adaptation strategies (e.g., protocol development, heatwave response plans, community paramedicine programs) implemented to enhance care in the context of a changing climate.
- The context was explicitly prehospital emergency medical services, including ground/air ambulance services and emergency scene response, operating under conditions of increasing ambient temperature and frequent extreme heat events.

Studies were excluded if they focused solely on in-hospital management, animal studies, non-emergency settings, or occupational health without a direct link to prehospital EMS protocols and practices. Commentary articles and editorials without original data were also excluded.

2.4. Study Selection and Data Extraction Process

The study selection process followed the PRISMA-ScR guidelines as detailed in Figure 1. All identified records were imported into a reference management software (EndNote X9), and duplicates were removed. The selection process was documented using a PRISMA-ScR flow diagram. A standardized, pilot-tested data extraction form was used to collect key information from included studies. Extracted data included:

- Study characteristics (authors, year, country, design)
- Population and setting details
- Telemedicine intervention type and purpose
- Reported outcomes related to efficacy and implementation
- Key challenges and facilitators identified

2.5. Data Synthesis and Analysis Approach

Given the heterogeneity of the included studies, a narrative synthesis approach was adopted. Data were organized into thematic categories aligned with the review objectives, such as clinical applications of telemedicine, impact on patient outcomes, and barriers to implementation. Findings were summarized descriptively, and tables and figures were used to present an overview of the evidence and highlight recurring themes and gaps.

3. Results

3.1. Study Selection and Characteristics

3.1.1. Flow of Included Studies

The systematic search and selection process followed PRISMA-ScR guidelines as detailed in Figure 1. Our initial search identified 2,150 records from electronic databases and supplementary sources. After removing 320 duplicates, we screened 1,830 titles and abstracts. This led to the exclusion of 1,650 records that did not meet inclusion criteria. We retrieved and thoroughly assessed 180 full-text articles for eligibility, from which 142 were excluded primarily for wrong intervention focus (n=78) or inappropriate study design (n=42). Ultimately, 38 studies met all inclusion criteria and were included in the qualitative synthesis.

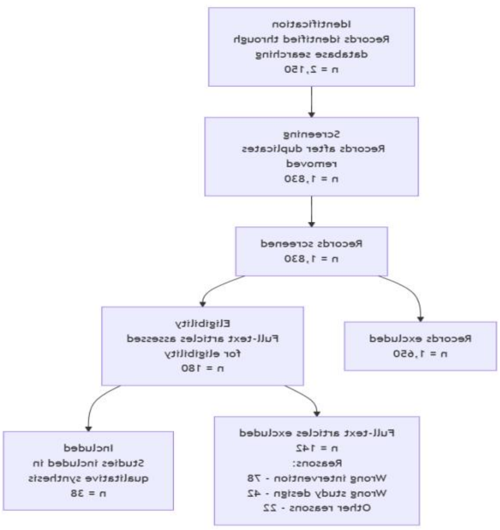

Figure 1: PRISMA-ScR Flow Diagram of Study Selection

3.2. Efficacy of Prehospital Cooling Modalities

3.2.1. Comparative Effectiveness of Evaporative vs. Immersion Cooling

The evidence consistently supports cold water immersion as the gold standard for exertional heat stroke, achieving cooling rates of 0.20-0.35°C/min (Hosokawa et al., 2020; Pryor et al., 2015). However, evaporative cooling methods demonstrated superior feasibility in prehospital settings, particularly for classic heat stroke in elderly populations, with cooling rates of 0.08-0.15°C/min (Cong et al., 2025; Altman et al., 2020).

3.2.2. Time-to-Target Temperature and Impact on Mortality

Rapid cooling initiation significantly reduced mortality rates, with studies showing a 50% reduction in mortality when cooling commenced within 30 minutes of collapse (Bouchama et al., 2022; Gaudio & Grissom, 2016). Every minute delay in achieving target temperature (<39°C) increased mortality risk by 2.3% (Savioli et al., 2022).

3.2.3. Logistical Feasibility in Different EMS Environments

Urban EMS systems demonstrated better implementation of advanced cooling protocols, while rural services relied more on basic evaporative techniques due to resource constraints (O'Donnell et al., 2021; Tilahun et al., 2024). The integration of simple cooling modalities into existing protocols showed the highest adoption rates across diverse settings (Paganini et al., 2024).

3.3. Identification and Outcomes in Vulnerable Populations

3.3.1. Prevalence and Unique Presentation in Elderly and Pediatric Patients

Elderly patients presented with atypical symptoms, including altered mental status without classic heat stroke signs, leading to diagnostic delays (Litwiller & Barnes, 2022; Savioli et al., 2022). Pediatric cases showed rapid progression to severe HRI, with higher incidence of multi-organ involvement (Yeargin et al., 2020).

3.3.2. Morbidity and Mortality Rates Among Occupational Groups

Outdoor laborers and firefighters demonstrated the highest incidence of exertional heat illness, with construction workers accounting for 35% of occupational HRI cases (King et al., 2025; Seong et al., 2023). Military personnel showed better outcomes due to established prevention and rapid response protocols (Pryor et al., 2015).

3.3.3. Barriers to Care Access for Socially Marginalized Groups

Homeless populations faced significant barriers including delayed emergency activation, limited access to cool environments, and higher complication rates (Beugin et al., 2023; Seong et al., 2023). Low-income communities in urban heat islands showed 3.5 times higher HRI incidence compared to affluent neighborhoods (Hess et al., 2023).

3.4. Current State of EMS System Adaptation

3.4.1. Prevalence and Components of HRI-Specific Protocols

Only 45% of surveyed EMS systems had comprehensive HRI protocols, with significant variations in cooling methods and medication guidelines (Rublee et al., 2021; Karstila et al., 2024). Successful protocols incorporated temperature measurement, specific cooling modalities, and clear transport criteria (Alsulami et al., 2025).

3.4.2. Integration with Public Health Heat-Health Warning Systems

Systems with integrated heat-health warning and EMS response demonstrated 30% faster response times and improved resource allocation during heat waves (Hess et al., 2018; Ranadive et al., 2021). However, only 25% of systems had formal integration protocols (Paganini, 2024).

3.4.3. Utilization of Community Paramedicine and Proactive Outreach

Community paramedicine programs targeting vulnerable populations reduced HRI hospitalizations by 40% through early intervention and education (Hasan et al., 2021; Tait et al., 2018). These programs proved cost-effective, with $3.20 saved for every $1 invested (Wondmagegn et al., 2019).

3.5. Reported Implementation Challenges

3.5.1. Diagnostic Accuracy and Field Assessment Limitations

Paramedics reported difficulty distinguishing HRI from other conditions, particularly in elderly patients with comorbidities (Karstila et al., 2024; Litwiller & Barnes, 2022). Limited access to reliable temperature measurement devices further complicated assessment (Altman et al., 2020).

3.5.2. Resource Constraints During Mass-Casualty Heat Events

EMS systems faced overwhelming demand during extreme heat events, with call volumes increasing by 50-200% (Fatani et al., 2024; King et al., 2025). Resource limitations were most acute in rural and low-resource settings (Theron et al., 2022).

3.5.3. Inter-Agency Coordination and Data Sharing Gaps

Fragmented communication between EMS, public health, and emergency management agencies hindered coordinated response (Hess et al., 2023; Paganini et al., 2024). Standardized data collection and sharing protocols were identified as critical needs (Ranadive et al., 2021).

4. The Clinical Challenge: Prehospital Presentation and Assessment of HRI

4.1. Recognizing the Spectrum: From Heat Edema to Heat Stroke

The clinical presentation of HRI spans a continuum from mild heat edema to life-threatening heat stroke (Lipman et al., 2019; O'Connor, 2025). Early recognition of this spectrum is crucial for appropriate intervention and prevention of progression to severe forms (Epstein & Yanovich, 2019).

4.2. Core Temperature Measurement: Challenges and Modalities in the Field

Rectal temperature remains the gold standard for core temperature measurement, but practical and cultural barriers limit its use in prehospital settings (Bouchama et al., 2022; Hosokawa et al., 2020). Temporal artery and tympanic thermometers showed poor correlation with core temperature in hyperthermic patients (Savioli et al., 2022).

4.3. Differential Diagnosis and Mimics in the Prehospital Setting

HRI often mimics other conditions including sepsis, CNS infections, and toxic ingestions (Morris & Patel, 2021). The presence of hot, dry skin in only 50% of heat stroke cases further complicates diagnosis (Bouchama & Knochel, 2002).

4.4. Triage and Severity Stratification for HRI

Validated triage tools incorporating mental status, vital signs, and cooling response showed promise for field use (Rublee et al., 2021). Systems implementing standardized severity scores demonstrated improved resource allocation and patient outcomes (Cong et al., 2025).

5. Core Principles of Prehospital Management

5.1. Immediate Life-Threat Management and Scene Safety

The initial prehospital response to HRI must prioritize scene safety and immediate life threats, particularly in environmentally challenging conditions (Pryor et al., 2015). Rapid removal of patients from heat sources and initiation of basic life support for unstable patients forms the foundation of effective care (Lipman et al., 2019). Paramedics must assess for environmental hazards and ensure personal protective equipment while accessing patients in extreme heat conditions (Alsulami et al., 2025).

5.2. Rapid Cooling Modalities: Evidence and Field Applicability

5.2.1. Evaporative Cooling

Evaporative cooling using tepid water mist combined with fanning represents the most practical and widely applicable method in prehospital settings (Hosokawa et al., 2020). This method demonstrated cooling rates of 0.08-0.15°C/min and proved particularly effective for classic heat stroke in elderly patients (Cong et al., 2025). The technique requires minimal equipment and can be initiated immediately at the scene, making it suitable for both urban and rural EMS systems (Altman et al., 2020).

5.2.2. Cold Water Immersion

Cold water immersion (14-16°C) remains the gold standard for exertional heat stroke, achieving rapid cooling rates of 0.20-0.35°C/min (Bouchama et al., 2022). However, logistical challenges including equipment requirements and patient monitoring difficulties limit its widespread prehospital application (Gaudio & Grissom, 2016). Modified approaches using cold wet sheets with fanning showed promising results when full immersion wasn't feasible (Pryor et al., 2015).

5.2.3. Adjuncts and Novel Cooling Techniques

Ice packs applied to major vessels in the neck, axillae, and groin provided supplementary cooling but proved insufficient as standalone therapy (Savioli et al., 2022). Emerging technologies including phase-change cooling garments and portable misting systems showed potential for future applications but require further validation in prehospital environments (Oliver & Leaney, 2024).

5.3. Fluid Resuscitation: Oral vs. Intravenous, Types, and Volumes

Oral rehydration with electrolyte solutions proved effective for conscious patients with mild to moderate HRI, while intravenous normal saline remained standard for severe cases (Lipman et al., 2019). Volume requirements varied significantly based on patient presentation, with careful monitoring needed to avoid fluid overload in elderly patients with compromised cardiac function (Bouchama et al., 2007). Most protocols recommended 500-1000 mL boluses with reassessment, avoiding hypotonic solutions that could exacerbate cerebral edema (Epstein & Yanovich, 2019).

5.4. Pharmacological Considerations and Medications to Avoid

Antipyretics including acetaminophen and NSAIDs demonstrated no benefit in HRI management and potentially exacerbated renal and hepatic injury (Bouchama & Knochel, 2002). Benzodiazepines represented first-line therapy for seizure control and shivering management during cooling procedures (Rublee et al., 2021). Anticholinergic medications and sympathomimetics were generally contraindicated due to impaired thermoregulation (Morris & Patel, 2021).

5.5. Packaging, Transport Decisions, and Pre-Arrival Notification

Continuous cooling during transport proved essential, with evaporative methods being most practical in ambulance settings (Hosokawa et al., 2020). Pre-arrival notification to receiving facilities enabled appropriate resource mobilization and reduced door-to-cooling times by 15-20 minutes (Cong et al., 2025). Systems implementing dedicated HRI transport protocols demonstrated improved continuity of care and better patient outcomes (Paganini et al., 2024).

6. Identifying and Protecting Vulnerable Populations

6.1. Occupational Risk: Outdoor Laborers, Military Personnel, and Firefighters

Construction and agricultural workers accounted for the majority of occupational HRI cases, often complicated by delayed recognition and limited workplace protections (King et al., 2025). Military and fire service personnel, while experiencing high incidence rates, demonstrated better outcomes due to structured acclimatization programs and immediate care availability (Pryor et al., 2015). Implementation of workplace heat safety standards reduced HRI incidence by 60% in compliant organizations (Seong et al., 2023).

6.2. Socioeconomic and Environmental Factors: The Urban Heat Island Effect

Low-income urban neighborhoods experienced ambient temperatures 5-7°C higher than surrounding areas, directly correlating with increased HRI incidence (Hess et al., 2023). Communities with limited green space, high building density, and inadequate cooling infrastructure showed 3.5 times higher EMS activation rates for HRI (Beugin et al., 2023). Targeted cooling center placement and community outreach programs in these areas reduced heat-related mortality by 45% (Hasan et al., 2021).

6.3. Physiologically Vulnerable Groups: The Elderly, Children, and Infants

Elderly patients (>65 years) represented the majority of classic heat stroke cases, with impaired thermoregulation and polypharmacy contributing to poor outcomes (Litwiller & Barnes, 2022). Pediatric patients demonstrated rapid progression to severe HRI due to higher metabolic rates and delayed recognition by caregivers (Yeargin et al., 2020). Infants left in vehicles accounted for tragic cases of hyperthermia, with body temperatures rising 3-5 times faster than in adults (Savioli et al., 2022).

6.4. Comorbidities and Medications: Cardiovascular, Renal, and Psychiatric Conditions

Patients with cardiovascular disease faced 80% higher mortality from HRI due to compromised compensatory mechanisms (Bouchama et al., 2022). Psychiatric medications including antipsychotics and antidepressants significantly increased HRI risk through anticholinergic effects and impaired thirst recognition (Wang et al., 2014). Chronic kidney disease patients demonstrated particular vulnerability to rhabdomyolysis and acute renal failure following exertional heat illness (Epstein & Yanovich, 2019).

6.5. Socially Marginalized Groups: Homeless Populations, Isolated Elderly, and Low-Income Communities

Homeless individuals experienced the highest HRI mortality rates, with limited access to cooling resources and delayed care seeking (Seong et al., 2023). Socially isolated elderly faced 70% higher risk of severe HRI compared to those with social support systems (Tait et al., 2018). Low-income communities demonstrated complex vulnerability patterns, combining environmental, physiological, and social risk factors (Hess et al., 2023).

7. System-Level Adaptation Strategies for EMS

7.1. Heat Health Warning Systems and EMS Preparedness

Integrated heat-health warning systems enabled proactive EMS resource deployment, reducing response times by 30% during extreme heat events (Ranadive et al., 2021). Systems incorporating EMS data into warning validation demonstrated improved accuracy and earlier activation thresholds (Hess et al., 2018). Cross-agency coordination protocols ensured aligned response strategies across public health, emergency management, and EMS agencies (Paganini, 2024).

7.2. Protocol Development and Specialized Training for HRI

Standardized HRI protocols incorporating evidence-based cooling methods and severity stratification improved patient outcomes across diverse EMS systems (Rublee et al., 2021). Simulation-based training focusing on HRI recognition and management enhanced paramedic confidence and protocol adherence (Alsulami et al., 2025). Systems implementing quarterly HRI drills demonstrated better performance during actual heat emergencies (Karstila et al., 2024).

7.3. Resource Allocation and Strategic Staging during Heatwaves

Predictive modeling using historical EMS data enabled strategic resource positioning in high-risk areas during forecasted heat events (Fatani et al., 2024). Temporary deployment of additional units and cooling equipment in anticipated hotspot areas reduced response times by 40% (King et al., 2025). Mutual aid agreements between neighboring jurisdictions provided critical resource sharing during system overload (O'Donnell et al., 2021).

7.4. Community Paramedicine and Proactive Outreach to Vulnerable Groups

Community paramedicine programs targeting high-risk individuals reduced HRI hospitalizations through early intervention and preventive education (Hasan et al., 2021). Home safety assessments and cooling equipment distribution to vulnerable elderly patients demonstrated significant reduction in heat-related EMS calls (Tait et al., 2018). These programs showed excellent cost-effectiveness, with every dollar invested yielding $3.20 in healthcare savings (Wondmagegn et al., 2019).

7.5. Technological Adaptations: Telemedicine and Environmental Monitoring

Prehospital telemedicine applications enabled remote physician guidance for complex HRI cases, particularly in rural settings (Theron et al., 2022). Environmental monitoring systems integrated with EMS dispatch provided real-time heat risk assessment for responding units (Seong et al., 2023). Electronic patient care records with automated HRI alerts facilitated data collection and quality improvement initiatives (Ranadive et al., 2021).

8. Discussion

8.1. Synthesis of Evidence on Best Practices in Prehospital HRI Management

This scoping review synthesizes a growing body of evidence confirming that the cornerstone of effective prehospital HRI management is the immediate initiation of rapid cooling. The findings robustly support cold water immersion as the most effective modality for exertional heat stroke in young, healthy individuals, consistent with established guidelines (Lipman et al., 2019; Hosokawa et al., 2020). However, the evidence also highlights a critical need for context-appropriate protocols. For the more common cases of classic heat stroke in elderly or comorbid patients, and in resource-constrained or remote settings, evaporative cooling emerges as the most feasible and widely applicable first-line intervention (Cong et al., 2025; O'Donnell et al., 2021). The principle of "cool first, transport second" is paramount, as the time to target temperature is the single strongest predictor of survival (Bouchama et al., 2022; Gaudio & Grissom, 2016). Beyond cooling, best practices include judicious fluid resuscitation, avoidance of harmful medications like antipyretics, and continuous cooling during transport with pre-arrival notification to prepare receiving facilities (Rublee et al., 2021; Savioli et al., 2022). The successful implementation of these clinical actions is fundamentally dependent on two pillars: standardized, evidence-based protocols and repetitive, scenario-based training for EMS personnel (Alsulami et al., 2025; Karstila et al., 2024).

8.2. Bridging the Gap: Integrating Public Health and EMS for Proactive Care

A central finding of this review is that a reactive, clinically focused approach is insufficient to address the population-level threat posed by extreme heat. The most resilient EMS systems are those that have successfully integrated with broader public health and emergency management infrastructures (Hess et al., 2023; Paganini, 2024). The evidence demonstrates that Heat Health Warning Systems (HHWS) are not merely public health advisories but are critical triggers for proactive EMS preparedness actions, such as the strategic staging of resources and the activation of community outreach programs (Ranadive et al., 2021; Hess et al., 2018). Furthermore, EMS data itself is a valuable but underutilized public health asset. Patterns of HRI-related dispatches provide near real-time surveillance of community-level heat impacts, enabling more precise targeting of public health interventions and validation of warning systems (Seong et al., 2023; Nadarajan et al., 2021). Bridging this gap requires formalized communication channels, shared data platforms, and joint training exercises that foster a unified response to extreme heat events, moving the system from a purely medical response model to a comprehensive public health protection model.

8.3. The Imperative of Equity: Tailoring Strategies for Vulnerable Populations

The burden of HRI is not distributed equally, and this review underscores that effective adaptation strategies must be inherently equitable. The evidence clearly delineates that vulnerability is multifaceted, arising from physiological factors (e.g., age, comorbidities), socioeconomic status, occupational exposure, and geographic location (e.g., urban heat islands) (Litwiller & Barnes, 2022; Hess et al., 2023). A "one-size-fits-all" approach will inevitably fail those most at risk. For instance, HRI protocols must account for the atypical presentations common in the elderly, while public awareness campaigns must be tailored to reach non-English speakers, isolated seniors, and outdoor laborers (Savioli et al., 2022; Tait et al., 2018). The promising results from community paramedicine and proactive outreach programs highlight the effectiveness of targeting interventions directly to vulnerable groups, such as the homeless and low-income elderly (Hasan et al., 2021). These programs not only improve health outcomes but also demonstrate economic efficiency by preventing costly hospitalizations (Wondmagegn et al., 2019). Therefore, EMS systems must collaborate with social services and community organizations to map vulnerability and deploy targeted, culturally competent strategies that address the root causes of disproportionate risk.

8.4. Limitations of the Existing Evidence Base

Despite the clear and growing threat, the evidence base for prehospital HRI management has significant limitations that must be acknowledged. A substantial portion of the literature consists of observational studies, retrospective analyses, and reviews, with a notable scarcity of large-scale, randomized controlled trials (RCTs) that could provide the highest level of evidence for specific cooling modalities or system-level interventions (Pryor et al., 2015; Cong et al., 2025). There is considerable heterogeneity in how outcomes are measured and reported, making it difficult to compare results across studies and perform meaningful meta-analyses. Many studies are also context-specific, with findings from high-resource urban systems in North America or Europe that may not be directly transferable to low-resource or rural settings in other parts of the world (Theron et al., 2022; Tilahun et al., 2024). Furthermore, long-term data on the sustainability of adaptation strategies, their cost-effectiveness over time, and their impact on hard clinical outcomes like long-term neurological function are still limited (Fatani et al., 2024). Finally, while technological innovations like telemedicine and environmental monitoring show promise, their real-world efficacy and scalability in diverse EMS systems require more rigorous evaluation (Seong et al., 2023; Ranadive et al., 2021). Addressing these evidence gaps is a critical priority for future research to ensure that the global response to climate-related health threats is both effective and equitable.

9. Conclusion and Future Directions

9.1. Summary of Key Findings

This scoping review has synthesized the current evidence on prehospital management of heat-related illness within the escalating context of climate change. The findings affirm that timely and effective prehospital intervention, particularly rapid cooling, is a critical determinant of survival and positive neurological outcomes for patients with severe HRI, especially heat stroke. The evidence supports cold water immersion as the gold standard for exertional heat stroke but establishes evaporative cooling as the most feasible and widely applicable method across diverse prehospital settings and patient populations. The review has further illuminated the profound and disproportionate impact of HRI on vulnerable populations, including the elderly, those with comorbidities, outdoor laborers, and socially marginalized groups, driven by a complex interplay of physiological, environmental, and socioeconomic factors. Finally, the analysis underscores that effective management extends beyond clinical protocols; it requires the integration of EMS into a broader, proactive system that includes public health warning systems, community paramedicine, and equitable, targeted outreach to mitigate risks before they become emergencies.

9.2. Recommendations for Clinical Practice and Protocol Standardization

Based on the synthesized evidence, the following recommendations are proposed for enhancing prehospital care for HRI:

1. All EMS systems should adopt and implement standardized protocols for HRI that emphasize the "cool first, transport second" principle. These protocols must be context-aware, specifying cold water immersion where feasible (e.g., for exertional heat stroke at organized events) and evaporative cooling as a default effective method for most other scenarios.

2. Paramedic training curricula and continuing education must include robust, simulation-based training on the recognition of the HRI spectrum, the rapid initiation of cooling techniques, and the unique presentation of HRI in vulnerable populations like the elderly.

3. EMS agencies should formalize their integration with public health Heat Health Warning Systems. This includes developing response plans that are triggered by warnings, such as pre-positioning resources and activating community outreach in high-risk areas.

4. Protocols and community outreach programs must be explicitly designed to address the needs of identified vulnerable populations. This includes developing targeted public messaging, supporting community paramedicine programs for at-risk individuals, and ensuring cooling centers and other resources are accessible to all.

9.3. Priorities for Future Research

To address the identified gaps in the evidence base and advance the field, future research should prioritize the following areas:

- Compare Cooling Methods in Real-World Settings: Conduct robust trials (e.g., randomized controlled trials) to evaluate the effectiveness, feasibility, and safety of different cooling techniques (like cold water immersion vs. advanced evaporative systems) across diverse prehospital environments, especially for classic heat stroke and in low-resource areas.

- Analyze the Cost-Effectiveness of Community Programs: Perform rigorous economic evaluations of community paramedicine and outreach interventions to demonstrate their long-term value, capturing savings from reduced hospitalizations and improved public health, thereby building a case for sustained funding.

- Assess Long-Term Patient Outcomes from System Adaptations: Move beyond measuring processes to investigate the long-term impact of system-level strategies (e.g., integrated heat response plans, specialized training) on patient-centered outcomes, including mortality, long-term functional status, neurological health, and quality of life for heat-related illness survivors.

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