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Critical Care and Early Management of Occupational Heat Stroke in Tropical and Low-Resource Settings: A Narrative Review

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ABSTRACT
Background: Occupational heat stroke is a life-threatening emergency that is increasingly prevalent in tropical regions with sustained heat and humidity. Outdoor and industrial workers face high risk due to environmental heat exposure and metabolic workload, leading to organ dysfunction and systemic inflammation. **Methods:** A narrative review of literature published between 2020 and 2025 was conducted using PubMed/MEDLINE, Scopus, and Web of Science focusing on occupational heat stroke, tropical climate, core temperature, and cooling strategies. **Results**: Occupational heat stroke remains under-recognized due to limited surveillance, diagnostic variability, and vulnerability among migrant and low-income workers. Pathophysiology involves elevated core body temperature and central nervous system dysfunction, triggering systemic inflammation and multi-organ failure. Rectal thermometry is the practical gold standard, while esophageal probes are preferred in intubated patients. Peripheral measurements frequently underestimate core temperature in humid tropical settings. When reliable thermometry is unavailable, diagnosis should be based on clinical features and immediate cooling. Prevention requires integrated strategies including work–rest cycles, hydration, heat acclimatization, environmental heat mitigation, and personal cooling systems. **Conclusion**: Rising global temperatures will increase occupational heat stroke in tropical regions. Improving access to accurate thermometry and implementing comprehensive workplace prevention strategies are essential to reduce morbidity.
Keywords: *Body temperature; Heat stroke; Low resource settings; Workplace environment*

INTRODUCTION

Occupational heat stroke is an increasingly critical clinical and public health concern, particularly in tropical regions where high temperatures and humidity persist year-round[1,2]. Workers in sectors such as agriculture, construction, logistics, mining, and manufacturing experience sustained thermal stress due to a combination of environmental heat, high metabolic workloads, and limited workplace protections[3]. Heat stroke represents the most severe form of heat-related illness and is characterized by central nervous system dysfunction accompanied by elevated core body temperature, leading to rapid multi-organ injury if not promptly treated[4,5].

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Despite its severity, occupational heat stroke remains substantially under-recognized and underreported across many tropical countries. Under-reporting is driven by gaps in national surveillance systems, inconsistent diagnostic criteria, limited access to healthcare, and structural vulnerabilities faced by migrant or informal workers, who may fear job loss or disciplinary action for reporting symptoms[6,7]. A major clinical barrier in these regions is the lack of reliable tools to measure core body temperature. Peripheral thermometry, commonly used in low-resource settings, often underestimates true core temperature in hot, humid environments, potentially delaying diagnosis and treatment[8,10].

Climate projections indicate that global heat exposure will intensify considerably over the coming decades. The International Labour Organization estimates that heat stress will result in the loss of more than 2% of total working hours by 2030, equivalent to approximately 80 million full-time jobs, with the greatest impact concentrated in tropical Asia[11]. As environmental heat exposure increases, timely recognition and effective clinical care of occupational heat stroke become increasingly vital.

Heat stroke may rapidly progress to multi-organ dysfunction requiring intensive care. The process may be exacerbated by translocation of bacteria or endotoxin through an intestinal wall rendered more permeable by the hyperthermia[36].

This narrative review synthesizes current evidence on the epidemiology, pathophysiology, risk factors, heat stress assessment, and prevention of occupational heat stroke, with a dedicated focus on clinical management in tropical and low-resource settings. Special emphasis is placed on the measurement of core body temperature 12-14. This remains a critical yet often under-addressed component of clinical care, particularly in settings where technological and infrastructural limitations frequently constrain diagnostic accuracy.

METHODS

This article adopts a narrative review methodology, which is appropriate for synthesizing heterogeneous evidence across clinical, occupational, environmental, and public health domains. A narrative review was chosen because occupational heat stroke spans multiple disciplines, studies incorporate diverse study designs, and encompasses emerging practices and policy considerations that are not readily comparable using systematic review methods. Furthermore, the goal of the present paper is to develop an integrated understanding of early identification and management strategies in tropical environments rather than quantitatively pooling outcomes.

Search Strategy and Sources of Information

A narrative review was conducted using literature published between 2020–2025 from PubMed/MEDLINE, Scopus, and Web of Science. Search terms included combinations of "heat stroke," "occupational heat stress," "tropical climate," "core temperature," and "cooling methods." Boolean operators ("AND," "OR") were used to refine search outputs. Only articles published in English were included in the search.

Foundational studies older than ten years were included selectively when no newer evidence was available. Evidence was synthesized into thematic domains of epidemiology, pathophysiology, risk factors, assessment, prevention, early recognition, clinical management, and considerations for low-resource tropical settings.

The search strategy was informed by previously published reviews on occupational heat illness and expert recommendations from American Conference of Governmental Industrial Hygienists, WHO, National Institute for Occupational Safety and Health, and international sports medicine societies.

Inclusion and Exclusion Criteria

Eligible studies included peer-reviewed publications addressing heat stroke or HRI in occupational or exertional settings; studies focusing on tropical, humid or high heat environments relevant to Southeast Asia or equatorial regions; and research providing data on diagnosis, temperature measurement, environmental heat assessment, or clinical management. Guidelines, consensus statements, and technical standards issued by authoritative bodies were also included.

Articles were excluded when it comprised non peer-reviewed commentaries without clinical applicability, focused on temperate climates, was limitied to conference abstracts without accessible full manuscripts , or comprised literature unrelated to occupational heat exposure

Approach to Data Synthesis

Narrative synthesis was guided by established frameworks. The extracted information was categorised into eight thematic domains to align with the objectives of the paper. These domains included the epidemiology and burden of occupational heat-related illnesses; pathophysiology; risk factors; assesessment of environmental heat stress; prevention strategies; early recognition; clinical management; and future research needs.

Each thematic domain was synthesized through comparative discussion of key findings, guideline recommendations, and practical considerations relevant to tropical environments.

RESULTS AND DISCUSSION

A total of 37 publications were included in the narrative synthesis, comprising 34 peer-reviewed articles and 3 reports and technical guidelines. Key characteristics and principal messages of the included sources are summarized in Table 1.

Theme: Epidemiology and Burden of Occupational Heat Related Illnesses

Occupational heat-related illness (HRI) is an increasingly important public health issue, particularly in tropical and subtropical regions where high ambient temperatures and persistent humidity amplify physiological heat strain. Existing evidence indicates that HRI remains substantially under-recognized and underreported despite being largely preventable[1]. Many countries rely on employer reporting, workers' compensation claims, or

Table 1. Summary of sources included in the narrative review

Sl.no.	Journal/Source	Authors	Year	Key message
1	Annual Review of Public Health	Kjellstrom T, Freitas C, Lemke B, Otto M, Briggs D.	2016	Heat exposure affects human performance and occupational health and is an important consequence of global climate change.
2	Annals of Internal Medicine	O'Connor FG	2025	Heat-related illnesses require prompt recognition and appropriate clinical management.
3	Frontiers in Public Health	De Sario M, de'Donato FK, Bonafede M, Marinaccio A, Levi M, Ariani F, Morabito M, Michelozzi P.	2023	Occupational heat stress is associated with health effects and substantial social and economic losses.
4	American Family Physician	Glazer JL	2005	Early recognition, cooling, and supportive management are central to heatstroke care.
5	New England Journal of Medicine	Epstein Y, Yanovich R	2019	Heatstroke involves severe hyperthermia and central nervous system dysfunction and can progress to multiorgan injury.
6	Industrial Health	Xiang J, Bi P, Pisaniello D, Hansen A	2014	Workplace heat exposure is associated with substantial health risks, particularly among vulnerable workers.
7	Annual Review of Public Health	Moyce SC, Schenker M	2018	Migrant workers experience important occupational health and safety vulnerabilities.
8	Scandinavian Journal of Medicine & Science in Sports	Racinais S, et al.	2015	Heat acclimatization and appropriate heat-management strategies reduce physiological strain during heat exposure.
9	Journal of Athletic Training	Ganio MS, et al.	2009	Temperature-measurement devices differ in validity and reliability during exercise in the heat.
10	British Journal of Sports Medicine	Byrne C, Lim CL	2007	Ingestible telemetric sensors provide a method for monitoring core body temperature during heat exposure.
11	International Labour Organization	International Labour Organization	2019	Heat stress can substantially reduce labour productivity and working hours, particularly in highly exposed regions.
12	Journal of Intensive Care Society	Patel J, et al.	2023	Heatstroke can cause systemic inflammation, multiorgan dysfunction, and critical illness requiring intensive care.
13	Scandinavian Journal of Medicine & Science in Sports	Périard JD, Racinais S, Sawka MN	2015	Heat acclimation produces physiological adaptations that improve tolerance to heat stress.
14	Journal of Occupational and Environmental Safety	Sobolewski A, et al.	2021	High humidity reduces evaporative cooling and increases physiological heat stress.
15	GeoHealth	Brimicombe C, et al.	2023	WBGT provides a comprehensive indicator of environmental heat risk.
16	NIOSH/CDC	NIOSH	2016	Occupational heat exposure requires systematic assessment, prevention, and worker protection measures.
17	ACGIH	ACGIH	2023	WBGT and metabolic workload can be used to guide occupational heat-stress exposure limits.
18	The Lancet Planetary Health	Flouris AD, et al.	2018	Occupational heat strain adversely affects workers' health and productivity.
19	Geoscientific Model Development	Casanueva A, et al.	2019	Heat-stress indices can be improved through appropriate climate modelling and bias correction.

20	Journal of Athletic Training	Hosokawa Y, et al.	2021	Environmental monitoring is an important component of heat-safety management during activities in the heat.
21	Medicine and Sport Science	Duffield R	2008	Cooling interventions can reduce physiological heat strain and support recovery from heat exposure.
22	Medical Journal of Malaysia	Mansor Z, et al.	2019	Adequate hydration practices can reduce the severity of heat-related illness among workers.
23	Indoor Air	Gao C, et al.	2012	Phase-change-material cooling can improve thermal comfort during heat exposure.
24	Materials	Ni X, et al.	2020	Personal cooling vests incorporating phase-change materials and fans can improve cooling effectiveness.
25	Wilderness & Environmental Medicine	Pryor RR, et al.	2015	Recognition of heat illness requires attention to environmental exposure and clinical symptoms.
26	Applied Ergonomics	Chang CH, et al.	2017	Heat stress can influence risk perception and risk-taking behaviour among workers.
27	International Journal of Environmental Research and Public Health	Hasan F, et al.	2021	Community-based education and interventions can improve prevention and management of heat-related illness.
28	Current Sports Medicine Reports	Casa DJ, et al.	2012	Exertional heatstroke requires rapid recognition, aggressive cooling, and appropriate supportive care.
29	European Journal of Medical Research	Cong S, et al.	2025	Prehospital cooling is important in heatstroke management, although implementation challenges remain.
30	PLoS ONE	Cain T, et al.	2025	Cold-water immersion is an effective cooling intervention with potential health and recovery benefits.
31	Temperature	Chalmers SM	2017	Cooling strategies can help manage heat strain during activity in hot and humid environments.
32	Current Sports Medicine Reports	Navarro CS, et al.	2017	Exertional heatstroke requires rapid intervention and effective cooling.
33	Journal of Athletic Training	Dykstra JH, et al.	2009	Different forms of ice produce measurable differences in tissue and surface temperature changes.
34	Temperature	Bongers CC, Hopman MT, Eijsvogels TM	2017	Cooling interventions vary in physiological effectiveness and practical applicability.
35	Critical Care	Bouchama A	2012	Heatstroke involves complex pathogenetic mechanisms and can lead to severe systemic complications.
36	Critical Care Medicine	Polderman KH	2009	Temperature management has important physiological effects but requires consideration of potential complications.
37	International Journal of Environmental Research and Public Health	Venugopal V, et al.	2015	Occupational heat stress profiles vary across workplaces and require context-specific risk assessment.
38	Medical Writing	Ferrari R	2015	Narrative reviews provide a structured approach for synthesizing heterogeneous evidence when quantitative pooling is not appropriate.

hospital-based diagnostic coding, all of which systematically underestimate true incidence. Underreporting is particularly common among low-wage and migrant workers who often have limited access to healthcare, inadequate knowledge of workers' rights, or fear punitive consequences when reporting symptoms[2].

Globally, HRI is most frequently observed in physically demanding sectors such as agriculture, construction, manufacturing, mining, and transportation. A systematic review has demonstrated consistently elevated rates of exertional heat illness across outdoor industries, highlighting that workers performing heavy labor in hot climates are at disproportionate risk[6]. In low- and middle-income countries (LMICs), this risk is further intensified by socioeconomic constraints, limited workplace protections, and inadequate cooling infrastructure [8].

Climate projections underline the urgency of this issue. The International Labour Organization estimates that by 2030, more than 2% of global working hours will be lost due to heat stress, equivalent to 80 million full-time jobs, representing substantial economic and productivity losses[11]. Tropical regions, particularly South and Southeast Asia, are expected to be most severely affected owing to the convergence of high heat exposure and labor-intensive economies. Without effective preventive measures and improved clinical recognition, occupational HRI is likely to escalate in both incidence and severity in the decades ahead.

Theme: Pathophysiology of Heat Stroke

Heat stroke represents the most severe form of HRI and arises when thermoregulatory mechanisms fail to dissipate sufficient heat. Under environmental or exertional heat stress, the body attempts to cool via sweating and peripheral vasodilation. However, these mechanisms become inadequate under conditions of high humidity, dehydration, intense physical exertion, or heavy protective equipment[9].

Heat stroke is clinically characterized by a core body temperature typically >40°C, and central nervous system dysfunction such as confusion, agitation, delirium, seizures, or coma[10]. Hyperthermia is directly cytotoxic, affecting membrane stability and trans membrane transport protein function, leading to intracellular electrolyte derangement. Protein, RNA, and NDA synthesis is impaired, with the later disrupted for longer[12]. Direct cell death in humans occurs at temperature of around 41^0C[12]. The thermal energy to cause cell death is similar to that required for protein denaturation, suggesting that hyperthermia induced cell death occurs primarily though disruption of protein structure[12]. The cellular and surrounding microenvironment is also susceptible to direct thermal injury after brief exposure to elevated temperatures. Interstitial changes as little as 30 minutes after exposure to temperature of 40.5^0C[12,26].

Secondary complications may include rhabdomyolysis, acute kidney injury from myoglobinuria, hepatic injury, disseminated intravascular coagulation, cardiovascular collapse, and multi-organ failure[13]. These complications emphasize the importance of early recognition and rapid cooling, as delayed treatment is closely associated with increased morbidity and mortality.

Theme: Risk Factors

Occupational HRI results from the interaction of personal susceptibility, environmental exposure, and the demands of work tasks.

Personal Risk Factors

Susceptibility increases with poor heat acclimatization, inadequate hydration, obesity, older age, sleep deprivation, febrile illness, and comorbid cardiovascular, renal, or metabolic disorders[14]. Several medications, including anticholinergics, beta-blockers, stimulants, and diuretics, may impair thermoregulation. Workers newly arriving from cooler climates or returning after illness require structured acclimatization programs as; lack of acclimatization substantially increases risk.

Environmental Risk Factors

Environmental heat arises from elevated ambient temperature, high humidity, direct solar radiation, low wind speed, and urban heat island effects[15]. In tropical climates, humidity frequently exceeds 80%, reducing evaporative cooling and causing significant thermal strain even at relatively moderate temperatures.

Occupational Risk Factors

High metabolic workload, prolonged shifts, inadequate rest cycles, impermeable personal protective equipment (PPE), lack of shade or cooling zones, and insufficient hydration access all raise occupational heat risk[16]. Outdoor workers in construction, landscaping, delivery services, logistics, and agricultural sectors are particularly vulnerable.

Theme: Assessment of heat stress

The Wet Bulb Globe Temperature (WBGT) index remains the gold standard for assessing environmental heat stress. It accounts for dry bulb temperature, humidity, radiant heat, and air movement, providing a comprehensive measure of environmental conditions[17]. ACGIH Threshold Limit Values (TLVs®) pair WBGT with metabolic workload to offer evidence-based exposure guidelines.

However, WBGT has significant limitations in real-world occupational settings, including the cost of monitoring equipment, the need for trained personnel, inadequate consideration of the burden imposed by PPE and difficulties in responding to rapidly changing outdoor conditions[18]. Consequently, many workplaces default to simpler but less accurate indicators such as the Heat Index, ambient temperature alone, or visual observation, each of which tends to underestimate risk, particularly in humid climates[19]. Wearable physiological sensors have emerged as promising tools, offering real-time measurement of heart rate, skin temperature, and sweat rate. While conceptually attractive for individualized risk prediction, their use is limited by cost, accuracy concerns in extreme climates, and lack of validated thresholds[20]. Further research is required before widespread adoption.

Theme: Prevention Strategies

Environmental and Urban Design

Heat reduction through environmental planning, such as expanding tree canopy, installing green roofs, increasing surface reflectivity, enhancing ventilation corridors, and integrating water features, can reduce ambient temperature by up to 1–4°C in tropical cities[21]. These interventions enhance worker safety and broader public comfort.

Workplace Engineering and Administrative Controls

Effective workplace strategies include scheduling physically demanding tasks during cooler hours, implementing structured work–rest cycles, ensuring adequate hydration (250–300 mL every 20 minutes), providing shaded or cooled rest areas, using fans or evaporative coolers when feasible, training supervisors to recognize early symptoms, and implementing gradual heat acclimatization programs[22]. These interventions have consistently reduced heat illness incidence across diverse industries.

Personal Cooling Technologies

Microclimate cooling technologies, including phase-change material (PCM) cooling vests, ice vests, and conductive cooling suits are promising adjuncts for reducing health related illnesses. PCM vests provide stable cooling without freezing, while conductive cooling suits such as graphite-enhanced PCM systems, can rapidly draw heat away from the body surface[23]. Evidence demonstrates that these technologies can improve physical comfort, reduce physiological strain, and enhance endurance during heat exposure[24].

Theme: Early Recognition

Timely recognition is essential to prevent progression from mild heat stress to life-threatening heat stroke. Early symptoms include dizziness, headache, fatigue, nausea, vomiting, excessive sweating or anhydrosis, muscle cramps, behavioral changes, confusion, and collapse[25]. Delayed reporting is common due to low awareness, cultural factors, and workplace pressure to continue working[26]. Worker education programs, visual prompts, and routine briefings significantly improve early detection and shorten time to intervention[27].

Theme: Clinical Management

Initial Evaluation

Key steps include assessment and securing of the airway, breathing, and circulation; measuring core body temperature and initiating immediate, aggressive cooling[28].

Core Body Temperature Measurement in Tropical and Low-Resource Settings

Accurate assessment of core body temperature is central to diagnosing and managing heat stroke[6,8]. Core temperature reflects the thermal state of deep tissues and organs. Peripheral measures such as oral or tympanic readings often underestimate the true temperature, especially in humid tropical environments.

Gold Standard Methods:

Pulmonary artery temperature is considered the most accurate measure of core body temperature. However, it requires invasive pulmonary artery catheterization and carries procedural risks, limiting its use primarily to specialized intensive care settings. Esophageal temperature measurement is also highly accurate and closely reflects rapid changes in body temperature, making it particularly suitable for intuabted patients. Rectal temperature remains the most practical gold standard in emergency and field settings because it provides a reliable and relatively accessible measure of core temperature [9,10.]

Alternate methods

When gold standard methods are unavailable, oral and tympanic temperature measurements may be used, although both have important limitations. Oral temperature can be significantly affected by recent fluid intake, mouth breathing and ambient heat. Tympanic temperature is influenced by factors such as earwax, sweat, humidity and incorrect probe positioning, making it less reliable during exertional heat illness.

Way forward for low-resource settings

In low-resource settings, accurate temperature measurement may be limited by the lack of rectal probes, unreliable digital devices, humidity related equipment failure and inadequate staff training. Practical approaches include the use of waterproof digital rectal thermometers, portable field probe kits and battery powered devices stored in sealed protective bags. When reliable temperature measurement is unavailable, the diagnosis should be guided by clinical features, including a history of heat exposure, collapse, altered mental status and hot skin. Importantly, cooling should be initiated immediately when heat illness is suspected and should not be delayed while awaiting temperature measurement [10].

Future developments, including wearable core temperature sensors, ingestible thermometric pills and integrated PPE monitoring systems, may offer useful alternatives, although further validation under tropical conditions is needed.

Cooling Strategies

Rapid cooling to below 38.9°C within 30 minutes of collapse is strongly associated with improved survival in patients. The time from collapse to initiation of cooling must be documented.

Effective methods include cold-water immersion, drenching with fanning, ice-water immersion, cold IV fluids, and ice packs applied to cooling points[30-33].

Cold-water immersion can limit procedural access and monitoring. Conduction-based cooling suits address many of these challenges by enabling effective cooling while maintaining necessary clinical access[30,34].

Intensive Care Management

Complications requiring intensive care monitoring include rhabdomyolysis, acute kidney injury, hepatic injury, Disseminated Intravascular Coagulation, cerebral edema, ARDS, and myocardial dysfunction. Targeted temperature management may be used, though evidence specific to heat stroke remains limited[35,36].

Theme: Future research needs

Future research should address important gaps in HRI prevention and management, including limited surveillance, insufficient data on vulnerable populations, lack of validated real-time monitoring tools, scarcity of field evaluations of cooling technologies, and inconsistent enforcement of occupational standards. Priorities include strengthening epidemiological surveillance, evaluating cost effective cooling interventions, validating monitoring sensors in tropical environments and conducting implementation research in high-risk tropical occupations[18,37].

CONCLUSION

Occupational heat stroke represents a growing clinical and public health threat in tropical environments where sustained high temperatures, humidity, and increasing outdoor labor demands intersect. The condition remains substantially under-recognized in many low- and middle-income countries due to limited surveillance, restricted diagnostic capability, and structural vulnerabilities among high-risk worker groups, including migrant and informal-sector laborers. The priorities are effective prevention strategies at a personal and workplace level, urgent diagnosis - often times relying on clinical diagnosis-, immediate cooling and supportive care, which may include multi-organ support in ICU.

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AUTHOR CONTRIBUTIONS:

Following authors have made substantial contributions to the manuscript as under:

AMY: Conceptualization, Design, writing

PSA: Conceptualization, review

ANU: Writing the manuscript

BPS: Conceptualization and writing the manuscript
APM: Conceptualization and review
AA: Conceptualization and design
PW: Conceptualization and design
BLR: Conceptualization and design
CP: Conceptualization and design
SC: Review
SB: Review
DGP: Conceptualization and design
S:Conceptualization and design
HH: Review
YSR: Design
Authors agree to be accountable for all respects of the work in ensuring that questions related to the accuracy and integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

None

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