One Health Bulletin 2026; 6(3): 118−125

johb.info

Review Article

One Health Bulletin

Prevention of heat−related illnesses in occupational settings: Emerging strategies for the Asia−Pacific region

Ahmed A. Almohammadi✉

Department of Preventive Medicine, Aldaitha Healthcare Center, Madinah Health Cluster, Ministry of Health, Madinah, Kingdom of Saudi Arabia

ABSTRACT

Heat-related illnesses (HRI) represent a growing occupational health challenge in the Asia-Pacific region, where an estimated 74.7% of workers are exposed to occupational heat stress. Workers in agriculture, construction, manufacturing, and outdoor service industries experience conditions ranging from heat cramps to fatal heat stroke. This narrative review examines current evidence on the epidemiology, physiological mechanisms, and prevention strategies of occupational HRI across Asia-Pacific countries. A systematic literature search was conducted using PubMed, Embase, and CINAHL databases for studies published between 2020 and 2025. Regional surveillance reveals 53 061 reported cases of occupational HRI in China, with an approximately 21% increase in risk for each 1 °C rise in ambient temperature. In India, up to 84% of workers report adverse health outcomes when workplace heat exposure exceeds recommended temperature thresholds. Climate projections indicate continued temperature increases across the region, with economic losses projected to reach approximately USD 2.4 trillion annually by 2030. South Asia alone is expected to lose 5% of working hours, equivalent to 43 million jobs. Evidence-based prevention strategies include the application of Wet Bulb Globe Temperature-based exposure limits (ranging from 25 °C to 31 °C depending on work intensity), structured 7-14 day acclimatization programs, and mandatory work-rest schedules. Policy frameworks vary substantially. While countries such as Singapore and Qatar have established legally binding protections, most informal-sector workers remain unprotected. Chronic health consequences including heat-associated kidney disease affect up to 42% of workers in some agricultural communities. Understanding and implementing effective occupational heat prevention strategies is increasingly critical as climate change continues to threaten worker health, labor productivity, and sustainable economic development in the Asia-Pacific region.

KEYWORDS: Heat-related illness; Occupational health; Heat stress prevention; Asia-Pacific; Workplace safety

1. Introduction

Heat-related illnesses (HRI) represent a spectrum of clinical conditions resulting from exposure to excessive heat, ranging from minor heat cramps and heat exhaustion to life-threatening exertional heat stroke[1]. The physiological mechanisms underlying these conditions involve thermoregulatory failure, cardiovascular strain, electrolyte imbalance, and in severe cases, systemic inflammatory responses leading to multi-organ dysfunction. The progression from mild to severe HRI often reflects the body's diminishing capacity to maintain thermal homeostasis when environmental heat stress exceeds physiological cooling capacity[1].

The Asia-Pacific region experiences some of the highest ambient temperatures globally, with climate change projections indicating mean surface temperature increases across all of Asia with very high confidence[2]. This region encompasses diverse climatic zones, from the tropical humid conditions of Southeast Asia to the extreme heat of the Persian Gulf states, and the temperate climates of East Asia and Oceania. These variations create distinct occupational heat exposure profiles, with South Asian workers facing prolonged monsoon heat combined with high humidity, Southeast Asian workers experiencing year-round tropical conditions, and workers in Gulf states confronting extreme dry heat during summer months[2].

✉To whom correspondence may be addressed. E-mail: ahmed.a.a11@outlook.com

This is an open access article distributed under the terms of the Creative Commons Attribution-Non-Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.For reprints contact: reprints@medknow.com

For reprints contact: reprints@medknow.com
©2026 *One Health Bulletin* Produced by Wolters Kluwer- Medknow.

How to cite this article: Almohammadi AA.Prevention of heat-related illnesses in occupational settings: Emerging strategies for the Asia-Pacific region. One Health Bull 2026; 6(3): 118-125. doi: 10.4103/ohbl.ohbl_118_25

Article history: Received 23 December 2025 Revision 22 January 2026
Accepted 3 March 2026 Available online 16 March 2026

Approximately 2.41 billion workers worldwide are exposed to excessive heat, with 74.7% of Asia-Pacific workers affected—the highest regional exposure rate globally[3]. This disproportionate burden reflects the region's concentration of labor-intensive industries, large outdoor workforce, rapid urbanization contributing to urban heat island effects, and substantial populations of informal sector workers lacking adequate protections. The agricultural sector alone employs hundreds of millions across the region, with workers regularly exposed to direct solar radiation during peak heat hours. Construction, manufacturing, and mining industries add millions more to heat-exposed populations, many working in environments where occupational heat stress is compounded by metabolic heat generation from physical exertion and heat-retaining personal protective equipment[3].

The economic burden is substantial. Excessive heat exposure is associated with an estimated 22.85 million occupational injuries and 18970 deaths annually worldwide[3]. Global productivity losses from heat stress are projected to reach USD 2.4 trillion annually by 2030, representing approximately 2.2% of total working hours lost[4]. The Asia-Pacific region faces particularly severe consequences, with South Asia projected to lose approximately 5% of working hours by 2030, equivalent to 43 million full-time jobs[4].

Climate change will substantially escalate these impacts. Heat extremes have increased while cold extremes decreased across Asia with high confidence, and South Asian heatwaves are projected to become more intense, more frequent, and longer in duration during the 21st century[2]. The Intergovernmental Panel on Climate Change (IPCC) projects that dangerous combinations of heat and humidity—measured by Wet Bulb Globe Temperature (WBGT)—will become commonplace in tropical regions, potentially exceeding human physiological limits during peak heat conditions. This trajectory necessitates comprehensive prevention strategies integrating evidence-based interventions across multiple levels: engineering controls, administrative controls including work-rest schedules and acclimatization programs, medical surveillance, and policy frameworks ensuring universal protection.

2. Methods

2.1. Review design and rationale

We conducted a narrative review to synthesize current evidence on occupational HRI prevention in the Asia-Pacific region. This methodological approach was selected because it allows comprehensive examination of diverse evidence types including epidemiological surveillance data, physiological studies, intervention trials, economic modeling, climate projections, and policy analyses. Systematic reviews with meta-analysis would have been limited by substantial heterogeneity in study designs, outcome measures, exposure assessment methods, and populations. Our objective was to provide a comprehensive overview with practical implications for occupational health practitioners, policymakers, and researchers while identifying critical research gaps.

2.2. Literature search strategy

A comprehensive literature search was conducted in PubMed/MEDLINE, Embase, and CINAHL databases. The search strategy employed combinations of terms: ("heat-related illness" OR "heat stress" OR "heat stroke" OR "heat exhaustion") AND ("occupational" OR "workplace" OR "worker") AND ("Asia" OR "Asia-Pacific" OR specific country names). Additional searches focused on interventions: "WBGT," "acclimatization," "work-rest schedules," and "heat action plans." Grey literature sources including International Labour Organization, World Health Organization and National Occupational Health Agencies were examined. Guidelines from National Institute for Occupational Safety and Health (NIOSH), American Conference of Governmental Industrial Hygienists (ACGIH), and International Organization (ISO) for Standardization were reviewed.

2.3. Inclusion and exclusion criteria

Studies were included if they: 1) were published between January 1, 2020 and December 31, 2025; 2) addressed occupational heat exposure or heat-related illness; 3) focused on Asia-Pacific region countries or provided globally relevant intervention data; 4) were published in English; and 5) included original research data, systematic reviews, meta-analyses, or authoritative guidelines. We excluded: 1) studies published before 2020; 2) case reports with fewer than 10 subjects; 3) non-occupational heat exposure studies; and 4) studies without quantitative data. The English-language restriction represents a limitation, potentially excluding relevant research in regional languages. The five-year publication window, while ensuring current evidence, may have excluded important foundational studies.

2.4. Data extraction and synthesis

Data were extracted on study characteristics, epidemiological measures [incidence, prevalence, mortality, relative risks (*RR*), odds ratios (*OR*) with confidence intervals (*CI*)], exposure assessment methods, climate projections, economic impacts, and intervention effectiveness. Given heterogeneity in study designs and outcomes, narrative synthesis was employed to integrate findings across domains, organized thematically by: 1) epidemiological burden and risk factors; 2) climate projections and economic impacts; 3) pathophysiological mechanisms and clinical manifestations; 4) evidence-based prevention strategies; and 5) policy frameworks and implementation considerations.

3. Epidemiology of occupational heat–related illnesses

3.1. Global and regional burden

HRI affect millions of workers worldwide, with the Asia-Pacific region experiencing disproportionately high rates. An umbrella review found that heat stress significantly reduces manual labor capacity—with decreases of 20%-60% in work output at high WBGT levels—and increases occupational injury risk through impaired cognitive function, reduced vigilance, and compromised motor coordination[5].

A systematic review and meta-analysis of 22 studies encompassing approximately 22 million occupational injuries found that injury risk increased 1% per 1 °C temperature rise (*RR* 1.010; 95% *CI* 1.009-1.011), with 17.4% increased risk during heatwaves (*RR* 1.174; 95% *CI* 1.057-1.291)[6]. When applied to large working populations exposed to temperature increases of 5 °C-10 °C above baseline during summer months, this translates to thousands of additional injuries annually.

Country-specific surveillance data reveal significant variations across the region. China's multi-provincial surveillance documented 53 061 heat-related illness cases across 11 provinces between 2013 and 2022, with peak incidence of 14 025 cases in 2022[7]. The analysis found a 21.03% increase in HRI risk per 1 °C ambient temperature rise (95% *CI* 20.59-21.47), with heat stroke showing a 62.48% risk (95% *CI* 60.01-64.98) increase per 1 °C[7]. However, reliance on passive surveillance likely underestimates true incidence, particularly among informal workers without health insurance. India's comprehensive occupational heat studies across eight industrial sectors documented that 70% of workers exceeded WBGT threshold limit values, with 84% of heat-exposed workers reporting adverse health outcomes[8]. The *OR* for adverse heat-related outcomes among heat-exposed versus unexposed workers was 2.3 (95% *CI* 1.74-3.19)[8]. This high prevalence of WBGT exceedances raises serious concerns about workplace protections and highlights gaps between established exposure limits and actual working conditions. South Korea's national cohort study analyzed 85.9 million person-years and identified 5342 heat effect cases, establishing an outdoor work mortality threshold at 31.2 °C WBGT[9]. Thailand's workplace surveillance documented that only 55% of workplaces complied with WBGT standards, with 43% symptomatic workers in non-compliant workplaces versus 18% in compliant workplaces[10]. Each 1 °C WBGT increase was associated with *OR* 1.85 (95% *CI* 1.44-2.48) for heat symptoms[10], demonstrating dose-response relationships and providing evidence that adherence to limits is protective. Australia's burden analysis quantified Disability-Adjusted Life Years attributable to heat-related occupational injuries during 2014-2019, identifying construction, agriculture, and mining as high-risk industries[11].

Analysis of surveillance data reveals important limitations. First, surveillance heterogeneity is substantial—China uses national diagnostic criteria, India uses WBGT exceedance plus physiological markers, South Korea relies on International Classification of Diseases-10 coding[7–9]. This methodological diversity limits direct comparisons. Second, notable data gaps exist for Southeast Asian nations including Indonesia, Philippines, Vietnam—with combined populations exceeding 500 million. Bangladesh and Pakistan have limited published surveillance data. Third, informal sector representation is critically deficient. Data primarily capture formal sector workers, while agricultural laborers, construction workers in small enterprises, street vendors—who constitute 60%-90% of the workforce in many countries—remain invisible in surveillance systems.

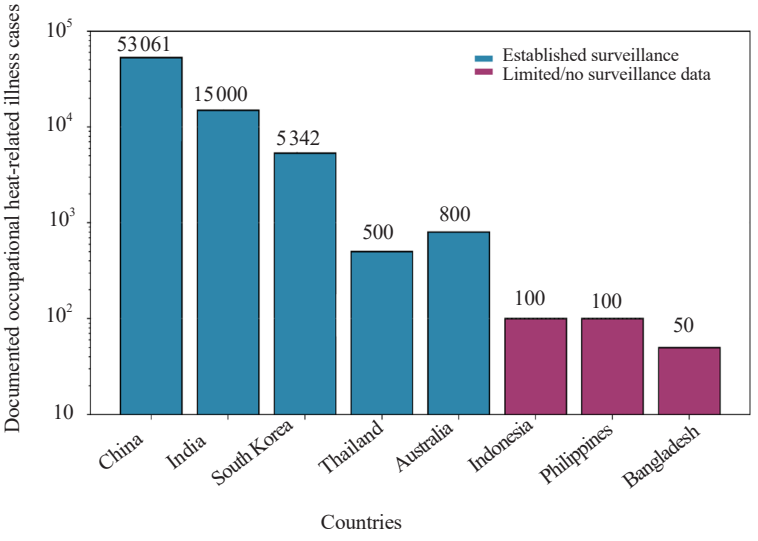


Figure 1. Distribution of documented occupational heat-related illness cases across major Asia-Pacific countries.

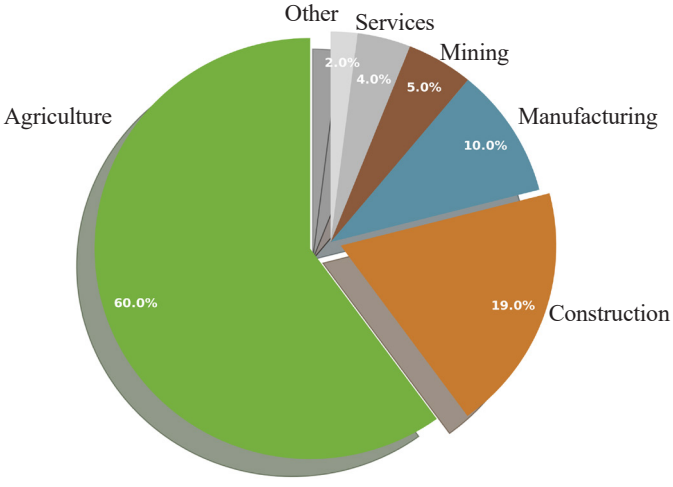


Figure 2. Sectoral distribution of heat-related economic productivity losses in the Asia-Pacific region. Note: Agriculture accounts for 60% of heat-related productivity losses despite representing a declining proportion of the regional workforce, highlighting vulnerability of outdoors physical labour.

As shown in Figure 1, the distribution of documented cases demonstrates substantial variation in heat-related illness surveillance across the Asia-Pacific region, with cases concentrated in countries with established surveillance while data is scarce in other equally populous nations. Countries with established surveillance systems report thousands of cases, with China documenting 53 061 cases across 11 provinces. In contrast, several populous nations including Indonesia, Philippines, and Bangladesh lack comprehensive occupational heat surveillance, representing critical data gaps. The logarithmic scale highlights the orders-of-magnitude difference between countries with robust surveillance infrastructure and those with limited data collection capacity. This disparity underscores the need for strengthened regional surveillance systems, particularly for informal sector workers who constitute 60%-90% of the workforce in many countries yet remain largely invisible in current surveillance systems.

3.2. Chronic health consequences

A particularly concerning long-term consequence is chronic kidney disease of non-traditional origin (CKDnt). A systematic review confirmed positive associations between high temperatures and kidney disease outcomes[12]. Field studies documented CKD prevalence up to 42% among men in agricultural communities, with annual incidence approximately 1% per year—25 times higher than rates in the United States or Europe[13]. These extraordinarily high rates occurring in young to middle-aged men without traditional risk factors represent a preventable occupational disease of staggering proportions. Progression to end-stage renal disease creates catastrophic economic impacts on families in low-income communities.

3.3. Risk factors and vulnerable population

A systematic review of 282 articles found that cardiovascular disease mortality increased 2.1% per 1°C temperature rise (*RR* 1.021, 95% *CI* 1.020-1.023), with heatwaves associated with 11.7% mortality increase (*RR* 1.117, 95% *CI* 1.093-1.141)[14]. Individual susceptibility factors are summarized in Table 1.

Unacclimatized workers face substantially elevated risk, comprising more than 75% of occupational heat deaths[1]. Migrant workers represent a particularly vulnerable population, facing compounding risks including recent arrival from cooler climates, limited language skills, economic pressures, inadequate recovery conditions, and limited healthcare access[3]. Workers with chronic conditions including kidney disease, cardiovascular disease, diabetes, and obesity experience elevated risks through impaired thermoregulation and reduced physiological reserve[14,1].

4. Climate projections and economic impacts

The IPCC Sixth Assessment Report confirms with high confidence that heat extremes have increased across Asia while cold extremes decreased[2]. South Asian heatwaves are projected to become more intense, frequent, and longer during the 21st century[2]. The critical distinction between ambient temperature and WBGT is essential—WBGT integrates humidity, air movement, and radiant heat, factors that profoundly affect heat dissipation through evaporative cooling. In humid tropical regions, WBGT can exceed safe working limits even when ambient temperature is below 35 °C, because high humidity prevents effective sweat evaporation.

Global projections estimate productivity losses reaching USD 2.4 trillion annually by 2030, representing 2.2% of total working hours lost, equivalent to 80 million full-time jobs[4]. South Asia faces approximately 5% working hour losses by 2030, equivalent to 43 million jobs, with India projected to lose 5.8% of working hours[4]. China's 2024 Lancet Countdown report documented USD 283.4 billion in productivity losses (1.65% of GDP) with 40.1 billion potential work hours lost—a 49% increase from baseline[15]. Agriculture experiences the highest losses, accounting for 60% of heat-related productivity decline, followed by construction at 19%[4]. As shown in Figure 2, the disproportionate economic impact of heat stress across different employment sectors. Agriculture accounts for 60% of total heat-related productivity losses despite representing a declining proportion of the regional workforce, reflecting the outdoor nature and high physical demands of agricultural labor. Construction contributes 19.0% of losses, followed by manufacturing (10.0%), mining (5.0%), services (4.0%), and other sectors (2.0%). The dominance of agriculture and construction highlights the particular vulnerability of outdoor physical labor to heat stress impacts. These sectors employ hundreds of millions of workers across the region who face direct solar radiation, limited access to cooling infrastructure, and work intensities that generate substantial metabolic heat, creating conditions where heat exposure frequently exceeds safe physiological limits.

These projections likely represent conservative estimates as they primarily capture reductions in work hours rather than costs associated with heat-related illness, mortality, and long-term health consequences. They may not fully capture non-linear effects of extreme heat events where productivity declines precipitously when physiological limits are exceeded. When WBGT exceeds 35 °C—projected with increasing frequency in tropical regions under high emissions scenarios—even acclimatized, healthy individuals cannot maintain thermal homeostasis indefinitely, implying potential for radical economic disruption beyond gradual productivity losses.

Table 1. Risk factors with defined outcomes and effect sizes.

Risk factor	Defined outcome	Effect Size (95% *CI*)	Reference
Per 1 °C temperature increase	Cardiovascular mortality	*RR* 1.021 (1.020-1.023)	[14]
Heatwave exposure	Cardiovascular mortality	*RR* 1.117 (1.093-1.141)	[14]
Per 1 °C temperature increase	Occupational injury	*RR* 1.010 (1.009-1.011)	[6]
Heatwave exposure	Occupational injury	*RR* 1.174 (1.057-1.291)	[6]
Per 1 °C WBGT increase	Heat symptoms in workers	*OR* 1.85 (1.44-2.48)	[10]
Heat-exposed *vs.* unexposed workers	Adverse health outcomes	*OR* 2.3 (1.74-3.19)	[8]
Unacclimatized status	Occupational heat death	>75% of fatalities	[1]

5. Clinical manifestations and pathophysiology

5.1. The spectrum of heat–related illness

HRI encompass a continuum from mild to life-threatening conditions. Heat cramps present as painful muscle contractions involving sodium depletion from profuse sweating. Heat exhaustion is characterized by inability to continue work due to cardiovascular insufficiency, with core temperature 38 °C-40 °C and intact central nervous system function. Management includes removal from heat, rest, and rehydration. However, heat exhaustion represents a continuum with heat stroke—if core temperature continues rising, progression occurs, emphasizing importance of aggressive cooling.

Heat stroke, defined by core temperature exceeding 40 °C with central nervous system dysfunction, represents the most severe manifestation[1]. Exertional heat stroke, most common in occupational settings, develops rapidly during intense physical activity. The pathophysiological cascade involves thermoregulatory overload leading to increased intestinal permeability ("leaky gut syndrome"), systemic inflammatory response, coagulopathy, and multi-organ failure[1]. Without treatment, mortality can exceed 50%.

5.2. Treatment principles

Cold water immersion represents the gold standard treatment, achieving cooling rates of 0.20 °C-0.35 °C per minute. Cooling to below 40 °C within 30 minutes of collapse is associated with near-100% survival[16]. For occupational settings, workplaces with high heat stress should have cold water immersion capability immediately available. Large agricultural operations, construction sites, and military facilities should maintain water tanks for emergency cooling rather than waiting for emergency medical services when brain injury is progressing.

Differential diagnosis must consider hypoglycemia, hyponatremia, and other causes, but any heat-exposed worker with core temperature >40 °C and altered mental status should be presumed to have heat stroke and immediately cooled.

6. Heat exposure assessment and prevention strategies

6.1. WBGT as the international standard

WBGT remains the internationally recognized standard, integrating ambient temperature, humidity, radiant heat, and air movement. NIOSH establishes reference WBGT values for acclimatized workers: 30.0 °C for light work, 27.8 °C for moderate work, 26.1 °C for heavy work, and 25.0 °C for very heavy work[17]. ACGIH 2024 TLVs provide consistent guidance, with values 2 °C-3 °C lower for unacclimatized workers[18]. A validation study found NIOSH WBGT limits demonstrated 100% sensitivity for detecting fatal heat stress conditions[19], providing strong evidence that adherence would prevent the vast majority of occupational heat deaths.

However, important limitations exist. WBGT-based limits assume standard clothing; workers wearing heavy personal protective equipment require lower limits. Individual susceptibility varies—older workers, those with chronic diseases, and those taking certain medications may require additional protection. WBGT monitoring requires specialized equipment, creating implementation barriers in small enterprises.

6.2. Engineering and administrative controls

Engineering controls modify work environments: shading (reducing WBGT by 3 °C-8 °C), cooling systems, radiant heat barriers, and ventilation. Administrative controls include work-rest schedules based on WBGT measurements. NIOSH provides detailed recommendations: when WBGT exceeds safe limits for continuous work, mandatory rest periods in cool environments are required[17]. The effectiveness depends on the rest environment—rest must occur in cooled areas to allow physiological recovery.

6.3. Hydration protocols

NIOSH recommends 240 mL water every 15-20 minutes, with maximum 1.5 liters per hour to avoid hyponatremia[17]. Total fluid needs can reach 10-15 liters per day for heavy labor in extreme heat. Urine color charts provide practical hydration monitoring, though evidence for behavior change is mixed. Electrolyte replacement is necessary when sweat losses exceed 5-6 liters daily. Implementation challenges include ensuring adequate, accessible, and palatable water at worksites.

6.4. Heat acclimatization

Acclimatization provides profound protection through earlier sweating onset, reduced electrolyte loss, expanded plasma volume (10%-20%), and improved cardiovascular stability. Research demonstrates 75%-80% adaptation is complete at 7 days, with full acclimatization at 10-14 days[16]. The "rule of 20%" provides practical guidance: New workers begin at 20% of full work duration on day 1, increasing by 20% daily[17]. Acclimatization decays after 3-4 days absence.

Critical implementation challenges include production pressures discouraging reduced work during acclimatization, difficulty in informal sectors, and logistical complexity of tracking individual status. A systematic review confirmed effectiveness of hydration, acclimatization, and modified work schedules[20]. ISO provides harmonized WBGT assessment methods consistent with NIOSH and ACGIH[21].

7. Policy frameworks and implementation

7.1. Singapore: Comprehensive regulatory framework

Singapore's Ministry of Manpower Framework employs a three-tier WBGT-based system: 32.0 °C to 32.9 °C triggers mandatory 10-minute hourly breaks for heavy work, 33.0 °C to 33.9 °C triggers mandatory 15-minute hourly breaks, for temperatures above 34.0 °C requires suspension of outdoor work or additional controls[22].

The framework mandates 7-day structured acclimatization and is legally enforceable with penalties. It requires proactive monitoring and provides clear, actionable thresholds. Singapore's approach is supported by established occupational health infrastructure, though challenges remain in smaller enterprises.

7.2. Qatar: Heat protection in extreme environments

Qatar's Ministerial Decision No. 17 of 2021 prohibits outdoor work from 10:00 AM to 3:30 PM during June 1 through September 15, with absolute work stoppage when WBGT exceeds 32.1 °C[23]. This addresses extreme conditions where temperatures reach 40 °C to 55 °C with humidity exceeding 80%. The time-based ban recognizes that during peak summer, afternoon outdoor work is categorically unsafe regardless of protective measures. However, enforcement challenges persist, particularly in small contractors and remote worksites.

7.3. China: Standards with implementation gaps

China has developed over 430 national occupational health standards including heat illness diagnosis (GBZ 41-2019) and workplace heat classification (GBZ/T 229.3-2010). However, occupational health services cover only approximately 20% of workers, with 200 million exposed to hazards lacking protection[24]. Challenges include insufficient professionals, fragmented oversight, and economic pressures favoring production. This illustrates a common pattern: technical standards exist but lack infrastructure, resources, and enforcement mechanisms for effective implementation.

7.4. Regional heterogeneity and the informal sector gap

Policy frameworks demonstrate marked heterogeneity. The most critical gap is exclusion of informal sector workers—street vendors, small-scale agricultural laborers, construction workers—who constitute 60%-90% of the workforce yet remain excluded from protections[3]. Extending protections requires community-based interventions, peer education, accessible cooling infrastructure, and potentially universal basic protections independent of employment status.

The International Labour Organization provides technical guidance advocating heat stress protections as fundamental worker rights[3]. Barriers to policy transfer include resource constraints, large informal sectors, economic competition, weak labor organizations, and governance challenges. Climate injustice compounds barriers—countries least responsible for emissions face most severe impacts yet have least resources for adaptation.

8. Discussion

This review reveals that occupational heat-related illness in the Asia-Pacific region presents an escalating crisis affecting approximately 1.8 billion workers. The convergence of climate change, economic development patterns, demographic factors, and governance gaps threatens worker health, economic productivity, and social equity.

8.1. Synthesis of evidence and critical appraisal

Epidemiological data demonstrate substantial burden, but surveillance heterogeneity and underascertainment mean documented cases represent the visible portion of larger burden—true burden potentially exceeds documented cases by factors of 5-10. The 21% risk increase per 1 °C may not be linear at extreme temperatures—evidence suggests exponential increases when WBGT approaches 35 °C. Current estimates focus on acute illness with insufficient attention to chronic consequences including CKDnt, where 25-fold increased kidney disease incidence suggests chronic impacts may ultimately exceed acute burden.

Projected USD 2.4 trillion annual productivity losses and regional GDP losses reaching 1.65% create imperatives for action. However, projections warrant critical appraisal—economic models assume gradual adaptation that is neither automatic nor equitable, requiring substantial investment constrained by technical limits, economic barriers, institutional resistance, and speed of change. When WBGT exceeds 35 °C—projected with increasing frequency—work becomes physiologically impossible, implying potential for radical economic disruption.

Evidence strongly supports WBGT-based limits, acclimatization programs, and work-rest schedules, with 100% sensitivity of NIOSH limits for predicting fatal conditions. Yet strong evidence contrasts sharply with weak implementation, reflecting knowledge gaps, resource constraints, economic pressures, power imbalances, and enforcement deficits. Bridging this requires awareness campaigns, subsidized equipment, revised regulations, strengthened enforcement, worker empowerment, and economic restructuring.

Singapore and Qatar implement comprehensive protections, enabled by strong state capacity, economic resources, and political will. However, these factors are absent in countries with most heat-exposed workers. The most critical gap is informal sector

exclusion, requiring fundamentally different approaches. Climate change and occupational heat stress raise profound ethical questions—workers most affected have contributed negligibly to emissions yet bear disproportionate impacts, embodying climate injustice.

8.2. Study limitations

This review is subject to several limitations. The inclusion of only English-language publications from 2020–2025 may exclude relevant evidence from regional literature and earlier foundational studies. More importantly, the available evidence and this synthesis do not systematically address how age, sex, or immigration status modify heat-related risks and protections. These factors are critical determinants of vulnerability but remain poorly documented in occupational heat studies, particularly for informal and migrant workers who constitute a large proportion of the exposed workforce. The findings are therefore most applicable to the formal sector and may not fully reflect the experiences of the most marginalized populations.

Addressing occupational heat stress requires transdisciplinary collaboration integrating climate science, occupational physiology, epidemiology, economics, engineering, social sciences, policy sciences, medical practice, and labor relations. Critical research gaps include surveillance improvements, implementation research, economic analyses, chronic health outcomes studies, vulnerable population research, adaptation limits, policy evaluations, and climate justice research.

9. Conclusions

HRI represent a significant and escalating occupational health challenge affecting 74.7% of Asia-Pacific workers with substantial health consequences and economic impacts creating both humanitarian and economic imperatives for comprehensive action.

Effective prevention requires multi-level interventions guided by strong evidence. WBGT-based exposure limits provide clear thresholds for workplace action. Structured acclimatization programs reduce heat illness risk by more than 75%. Hydration protocols maintain thermoregulatory capacity. Mandatory work-rest schedules prevent excessive heat strain. Engineering controls modify work environments to reduce heat exposure.

However, evidence-based interventions alone are insufficient without supportive policy frameworks ensuring universal implementation. Regional analysis reveals substantial heterogeneity, with Singapore and Qatar implementing comprehensive, legally binding protections while most countries lack enforceable standards, particularly for informal and migrant workers who constitute the majority yet remain excluded from regulatory protections.

The disparity between policy development and implementation represents the most significant barrier to reducing occupational heat-related morbidity and mortality. Bridging this gap requires strengthening surveillance systems, enforcing existing regulations through adequately resourced inspectorates, extending coverage to informal workers through innovative community-based approaches, building capacity of occupational health professionals, and empowering workers through strengthened labor organizations. Climate projections indicating continued temperature increases, with South Asian heatwaves becoming more intense and dangerous heat-humidity combinations becoming commonplace in tropical regions, underscore urgent need for transformative adaptation strategies. Without comprehensive intervention, tens of millions of workers face increased risk of heat illness, injury, chronic disease, and premature mortality, while economic productivity losses threaten development goals.

Ultimately, protecting workers from occupational heat stress is inseparable from broader climate action. Mitigation to limit warming remains essential, as adaptation has limits—some projected future conditions may exceed human physiological tolerance for outdoor work. Climate justice demands that workers bearing disproportionate climate impacts receive adequate protection and support. The health and productivity of 1.8 billion Asia-Pacific workers, and the economic futures of nations across the region, depend on comprehensive, equitable, and evidence-based action to address the escalating crisis of occupational heat stress.

Conflict of interest statement

The authors declare that there is no conflict of interest.

Funding

This study received no extramural funding.

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon request.

References

[1] Garcia CK, Renteria LI, Leite-Santos G, Leon LR, Laitano O. Exertional heat stroke: Pathophysiology and risk factors. *BMJ Med* 2022; **1**(1): e000239.

[2] Intergovernmental Panel on Climate Change. *Regional Fact Sheet–Asia*. In: *Climate change 2021: The Physical science basis. Contribution of working group I to the sixth assessment report*. Cambridge: Cambridge University Press; **2021**.

[3] International Labour Organization. Flouris A, Azzi M, Graczyk H, Nafradi B, Scott N, eds. *Heat at work: Implications for safety and health*: *A global review of the science, policy and practice*. [Online] Available from: https://

www.ilo.org/sites/default/files/2024-07/ILO_OSH_Heatstress-R16.pdf. [Accessed on 21 October 2025].

[4] International Labour Organization. *Working on a warmer planet: The impact of heat stress on labour productivity and decent work*. [Online] Available from: https://www.humanitarianlibrary.org/sites/default/files/2023/09/Working%20on%20a%20Warmer%20Planet%20-%20The%20Impact%20of%20Heat%20Stress%20on%20Labour%20Productivity%20and%20Decent%20Work.pdf. [Accessed on 21 October 2025].

[5] Morris NB, Jay O, Flouris AD, Casanueva A, Gao C, Foster J, et al. Sustainable solutions to mitigate occupational heat strain–An umbrella review of physiological effects and global health perspectives. *Environ Health* 2020; **19**: 95.

[6] Fatima SH, Rothmore P, Giles LC, Varghese BM, Bi P. Extreme heat and occupational injuries in different climate zones: A systematic review and meta-analysis. *Environ Int* 2021; **148**: 106384.

[7] Wang Z, Ma R, Wang X, Mo F, Zhao Y, Geng Y, et al. Individual-level, multi-provincial analysis of high temperature and heat-related illness association—China, 2013-2022. *China CDC Wkly* 2025; **7**(45): 1413-1417.

[8] Venugopal V, Latha PK, Shanmugam R, Krishnamoorthy M, Omprashanth R, Lennqvist R, et al. Epidemiological evidence from south Indian working population—the heat exposures and health linkage. *J Expo Sci Environ Epidemiol* 2021; **31**: 177-186.

[9] Yoon JH, Lee WT, Yoon MJ, Lee W. Risk of heat-related mortality, disease, accident, and injury among Korean workers: A national representative study from 2002 to 2015. *GeoHealth* 2021; **5**(12): e2021GH000516.

[10]Phanprasit W, Rittaprom K, Dokkem S, Meeyai AC, Boonyayothin V, Jaakkola JJK, et al. Climate warming and occupational heat and hot environment standards in Thailand. *Saf Health Work* 2021; **12**(1): 119-126.

[11]Varghese BM, Liu J, Hansen A, Bi P, Pisaniello D, Nitschke M, et al. The burden of occupational injury attributable to high temperatures in Australia, 2014-19. *Med J Aust* 2023; **219**(11): 542-548.

[12]Liu J, Varghese BM, Hansen A, Zhang Y, Driscoll T, Morgan G, et al. Hot weather as a risk factor for kidney disease outcomes: A systematic review and meta-analysis. *Sci Total Environ* 2021; **801**: 149806.

[13]Elinder C-G. Heat-induced kidney disease: Understanding the impact. J *Intern Med* 2025; **297**(1): 101-112.

[14]Liu J, Varghese BM, Hansen A, Xiang J, Zhang Y, Dear K, et al. Heat exposure and cardiovascular health outcomes: A systematic review and meta-analysis. *Lancet Planet Health* 2022; **6**(6): e484-e495.

[15]Cai W, Zhang C, Zhang S, Ai Y, Bai W, Bao J, et al. The 2024 China report of the Lancet Countdown on health and climate change: Launching a new low-carbon, healthy journey. *Lancet Public Health* 2024; **9**(12): e1070-e1088.

[16]Eifling KP, Gaudio FG, Dumke C, Lipman GS, Otten EM, Martin AD, et al. Wilderness medical society clinical practice guidelines for the prevention and treatment of heat illness: 2024 update. *Wilderness Environ Med* 2024; **35**(1_suppl): 112S-127S.

[17]National Institute for Occupational Safety and Health. *Criteria for a recommended standard: Occupational exposure to heat and hot environments*. [Online] Available from: https://www.cdc.gov/niosh/docs/2016-106/. [Accessed on 20 July 2025].

[18]American Conference of Governmental Industrial Hygienists. *2024 TLVs and BEIs based on the document of threshold limit values for chemical substances and physical agents & biological exposure indices*. Cincinnati: American CGIH; **2024**.

[19]Tustin AW, Lamson GE, Jacklitsch BL, Thomas RJ, Hodgson MJ, Gibbs JL, et al. Evaluation of occupational exposure limits for heat stress in outdoor workers—United States, 2011-2016. *MMWR Morb Mortal Wkly Rep* 2018; **67**: 733-737.

[20]Habibi P, Razmjouei J, Moradi A, Mahdavi F, Fallah-Aliabadi S, Mohammadi J. Climate change and heat stress resilient outdoor workers: Findings from systematic literature review. *BMC Public Health* 2024; **24**: 1711.

[21]International Organization for Standardization. *ISO 7243:2017 Ergonomics of the Thermal Environment—Assessment of Heat Stress Using the WBGT Index*. [Online] Available from: https://www.iso.org/standard/67188.html. [Accessed on 5 November 2025].

[22]Ministry of Manpower Singapore. *Heat stress measures for outdoor Work: Revised Framework*. [Online] Available from: https://www.preventionweb.net/publication/policies-and-plans/singapore-heat-stress-measures-outdoor-work. [Accessed on 3 June 2025].

[23]State of Qatar Ministry of Labour. *Ministerial Decision No. 17 of 2021 on Heat Stress*. [Online] Available from: https://www.ilo.org/resource/qatars-ministerial-decision-heat-stress. [Accessed on 1 December 2025]

[24]Xu XY, Ren PH, Shi WY, Deng FD, Wang QF, Shi ST, et al. Occupational health and safety regulations in China: Development process, enforcement challenges, and solutions. *Front Public Health* 2025; **13**: 1522040.

Publisher' s note

The Publisher of the Journal remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Edited by Qi Y, Liang TC