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RESEARCH ARTICLE

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How Effective are Heat Stress Interventions at Impacting Outdoor Workers' Well-Being and Quality of Life?: A Systematic Review

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ABSTRACT

Background: Outdoor workers are prone to heat stress due to prolonged exposure to extreme heat, especially during the summer, leading to heat-related illnesses and injuries, including acute kidney injury. Agencies, including California Division of Occupational Safety and Health (CAL/OSHA), The Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH), American Conference of Governmental Industrial Hygienists (ACGIH) and International Organization for Standardization (ISO) have developed guidelines to assess and prevent heat stress. Early interventions, including Water Rest Shade (WRS) have been designed to mitigate heat stress and heat-related conditions.

Objective: To identify current best practices of heat stress interventions among outdoor workers and their impact on well-being and quality of life.

Methods: A literature search was conducted across four databases for studies between 2012-2023. Data abstraction was standardized and analysed descriptively.

Results: Thirty-six studies were reviewed, identifying six designed interventions for outdoor workers. Significant heterogeneity was observed across methodological approaches, the populations, and study durations. The reviewed studies provided valuable insights into the effectiveness of various interventions, emphasizing the importance of comprehensive strategies incorporating multiple interventions, including hydration practices, rest breaks, cooling measures, training, and environmental monitoring to mitigate heat stress. The WRS intervention was mostly effective in mitigating heat stress, heat-related injuries and illnesses, and fatalities.

Conclusion: The effectiveness of heat stress interventions varies, but no single approach is sufficient alone to mitigate heat stress.

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KEYWORDS

Heat-Related Injuries/illnesses (HRIs); Water Rest Shade (WRS); Wet-Bulb Globe Temperature (WBGT); Core Body Temperature (CBT); National Institute for Occupational Safety and Health (NIOSH); American Conference of Governmental Industrial Hygienists (ACGIH); Occupational Safety and Health Administration (OSHA); International Organization for Standardization (ISO 7243).

Introduction

Outdoor workers, particularly in construction and agriculture, face significant heat stress due to extreme heat exposure, which peaks during summer, leading to Heat-Related Injuries and Illnesses (HRIs) and even fatalities. Research findings show a strong association between heat exposure and both direct and indirect risk factors for occupational injury, with temperature fluctuations amplifying workplace injury risks across different worker demographics [1]. A meta-analysis across various occupations in 30 countries found that 15% of individuals experienced Acute Kidney Injury/Illness (AKI) due to frequent heat stress exposure [2]. In the USA, analysis of the Washington state workers' compensation state fund HRI claims data (2006-2021) showed that construction and agriculture industry accounted for nearly one-third of all HRI claims, particularly on days with sudden temperature spikes [3]. Additionally, between 2011 and 2020, the USA bureau of labor statistics reported 400 heat-related fatalities, with a significant portion occurring in the construction (n=124), and agriculture (n=43) sectors [4]. During this period, non-fatal injury rates involving days away from work decreased from 0.4 per 10,000 Full-Time Employees (FTE) in 2011 to 0.2 per 10,000 FTE in 2020, albeit with fluctuations between 2014 and 2019, with similar declines in construction (from 1.7 to 0.6 per 10,000 FTE) and agriculture (from 1.8 to 0.9 per 10,000 FTE) [5].

Various organizations, including the American Conference of Governmental Industrial Hygienists (ACGIH), the International Standard Organization

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(ISO), and the National Institute for Occupational Safety and Health (NIOSH), have issued guidelines to mitigate heat exposure risks. However, only a few states, including California, Washington, Oregon, Colorado, Nevada, Virginia, and Maryland, have established specific heat stress standards to address outdoor workers' heat exposure for temperatures ≥ 80°F or ≥ 90°F. Recently, Michigan introduced a State Emphasis Program for heat-related hazards. Despite these efforts, the USA Occupational Safety and Health Administration (OSHA) has not yet enacted a specific heat stress standard but has launched initiatives, including the Heat Illness Prevention campaign and the National Emphasis Program in 2022, with the Small Business Regulatory Enforcement Fairness Act process in 2023 for measures to address heat stress. These early interventions include but are not restricted to, implementing "Water Rest Shade" (WRS), training, and acclimatization procedures for new or returning employees [6].

In addition to these recommended measures, researchers and individual industries have implemented various interventions, including the use of cooling vests and bandanas, to prevent heat stress among construction and agriculture workers [7-13]. These interventions have shown potential in reducing heat-related incidents and associated costs. For instance, a retrospective cohort study in Central Texas found that a Heat Stress Awareness Program among outdoor municipal employees led to a 50% reduction in workers' compensation costs and total HRI cases after the program's implementation [14]. Similarly, a systematic review assessing cooling interventions across four occupations concluded that cooling vests, hydration, and resting in the shade could reduce disproportionate HRI rates and fatality among vulnerable occupational groups [13]. However, these interventions' long-term effectiveness and broader impact on outdoor workers' well-being and Quality of Life (QOL) are yet to be determined.

Given the projected rise in temperatures and associated health risks due to climate change, continuously assessing and improving heat stress programs/interventions is crucial because of the significant impact of extreme heat on safety, health, and productivity. A recent USA study found that extreme heat is associated with 1,651 excess cardiovascular deaths annually from 2008 to 2019, which is projected to increase by 162% by the mid-century period (2036-2065) [15]. Therefore, identifying best practices in heat stress management could help policymakers develop robust guidelines to protect outdoor workers' health and well-being. Based on this, we aimed to identify current best practices of heat stress interventions designed for outdoor workers and their influence on workers' well-being and QOL, with the goal of informing policies and guidelines for worker protection and well-being.

Materials and Methods

The study design

This review analysed all evidence that answers the following question: (i) what are the characteristics of heat stress intervention/prevention programs for outdoor workers? (ii) Are the interventions meeting the program's intended goal(s) (i.e., to reduce HRIs and fatality, protect workers' well-being, and QOL)? The review procedures and search strategy followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines and the Population Intervention Comparison Outcome (PICO) framework (Table 1), respectively [16]. The eligibility criteria for inclusion were restricted to peer-reviewed studies published between January 1, 2012, and July 14, 2023, on heat stress and prevention programs/interventions.

Table 1. PICO search strategy.

Domain	Target	Search terms
Population	Outdoor workers	Construction workers
		Farmers
		Agriculture workers
		Miners
Intervention	Heat stress	Heat stress intervention
		Heat stress prevention program
Comparison	NIOSH	Heat stress recommended guideline
Outcome	Heat-related issues	Heat-related injuries/illnesses
	-	Fatalities
	Quality of life	Well-being

Inclusion criteria

Due to the limited number of studies on construction workers, this review included global studies on outdoor workers, including construction workers, farmers, and miners, because these groups spend most of their time working outside and are frequently exposed to natural environmental heat. Both qualitative and quantitative studies were included.

Exclusion criteria

Excluded were studies on indoor workers, non-workforce populations (e.g., nursing home residents), outdoor workers under 18 years, and those exposed to anthropogenic heat (e.g., firefighters). Studies on climate-related environmental heat exposure on the general population were excluded. Also, studies that assessed non-surface miners were excluded. Figure 1, summarizes the PRISMA protocol.

Literature search and selection

Peer-reviewed articles (2012-2023) were searched using keywords, including "heat stress," "construction," "farmer," and "mining", combined with Boolean operators (AND, OR, NOT) across four databases: PubMed, Embase, CINAHL Plus, and Web of Science. Results were imported into a citation manager. Independently, two reviewers screened titles, abstracts, and full texts against eligibility criteria. Discrepancies were resolved by a third reviewer, with final decisions made by consensus between the initial reviewers.

Data extraction

Two reviewers independently extracted data from eligible articles, focusing on: (i) population variables, including sample size; (ii) intervention type/duration; (iii) comparison variables; and (iv) outcome variables, including the reported heat-related issues and QOL constructs as defined by the Centres for Disease Control and prevention (CDC) [17].

Quality assessment

Two reviewers independently appraised the studies' quality using standard tools: (i) Joanna Briggs Institute Critical Appraisal Tools (https://jbi.global/critical-appraisal-tools) for cross-sectional, qualitative, randomized trial and quasi-experimental studies, and (ii) Mixed Method Appraisal Tool (MMAT) [18-23]. Cross-sectional, qualitative, quasi-experimental, and randomized control-trial studies were evaluated with 8-item, 10-item, 9-item, and 13-item appraisal questions, respectively, with responses marked as 'Yes,' 'No,' 'Unclear,' or 'Not applicable.' A quality range based on similar reviews was adopted to determine whether to include or exclude each study [24]. Cross-sectional studies scoring 4 or more "Yes" responses, and qualitative studies scoring 5 or more, were deemed high quality [24]. Following Liu et al., approach, we developed a quality rate for randomized control trials and quasi-experimental studies [24]. Studies scoring 7 or more and 5 or more "Yes" responses, respectively, were considered high quality. Reviewer responses were compared, and discrepancies were resolved through discussion.

For MMAT, studies were assessed against five criteria, with 'Yes,' 'No,' or 'Can't tell' responses. In the MMAT 2018 update, the authors discouraged calculating the overall score [23]. However, we adapted a ranking system based on similar reviews to convey the results easily [25,26]. The appraised articles were classified as high if all the five ranking criteria were met, medium if four, and low if three or fewer were met [25,26]. Reviewers' responses were compared and disagreements between ranked studies were also resolved through discussion until a consensus was met.

Results

The initial search yielded 3,625 peer-reviewed articles, with 3,314 unique studies after removing 331 duplicates (Figure 1). A preliminary screening of titles and abstracts led to the exclusion of 2646 articles due to unavailable abstracts and ineligibility of titles and abstracts. Subsequently, 632 studies were excluded for various reasons, including failure to meet inclusion criteria and involved simulated studies. Thirty-six full-text articles that met the inclusion criteria were selected. Simulated studies were excluded to avoid potentially misleading or incomplete results that may not reflect real-world work environments.

Descriptive characteristics of the included studies

The eligible studies were conducted across 14 countries covering six continents (Table 2), and the critical study characteristics were summarized (Supplementary Table 1) [27-62]. Most studies were conducted in the USA (n=16, 44.4%), predominantly focusing on the agricultural sector (n=15, 41.6%) (Table 2). This suggests a strong focus of researchers on agricultural workers, with fewer studies on construction workers and miners. Most of the studies were cross-sectional (n=16, 44.4%) (Figure 1). Thirty-three studies (91.7%) were rated as high quality, while 3 (8.3%) were rated as low quality (Supplementary Table 1 and Table 2a-2e) [27-62].

The most frequently reported interventions were environmental monitoring (n=25) [27-51] and hydration practices (n=25) (Supplementary Table 1) [27,30,32-37,39-41,43,44,46-50,52-58]. Conversely, the least interventions were the (i) multi-level Heat Education and Awareness Tool (HEAT) and the OSHA-NIOSH heat safety mobile phone app (n=5) and (ii) state OSHA heat illness prevention programs and municipal level heat safety programs (n=3) (Supplementary Table 1) [39, 45,51-53,57, 59-60].

Table 2. Study site by industry and continent (n=36).

Industry	Continent	Countries	Studies n (%)
Agriculture	North America	USA	15 (41.6)
	Central America	Nicaragua	2 (5.5)
	Central America	Guatemala	1 (2.7)
	Central America	Mexico	1 (2.7)
	Central America	El Salvador	2 (5.5)
Construction	North America	USA	1 (2.7)
	Asia (East)	Hong Kong	3 (8.3)
	Asia (East)	India	1 (2.7)
	Asia (East)	Japan	1 (2.7)
	Asia (East)	China	1 (2.7)
	Asia (West)	Iran	2 (5.5)
	Asia (West)	Saudi Arabia	1 (2.7)
	Asia (West)	United Arab Emirates	1 (2.7)
	Africa (North)	Egypt	1 (2.7)
Mining	Asia (West)	Iran	2 (5.5)
	Oceania	North Australia	1 (2.7)

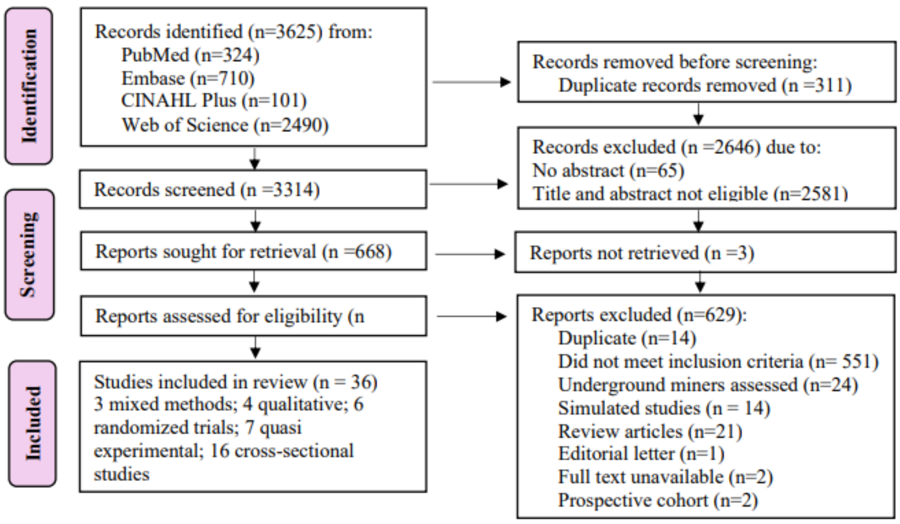

Figure 1. Study selection Prisma flow diagram.

Current heat stress interventions and effectiveness per intent

Acclimatization

This is the body's physiological adjustments to repeated heat exposure to reduce strain caused by heat stress allowing a person to work more efficiently while lowering the risk of heat-related injury. Acclimatization was operationalized differently across the reviewed studies. Six studies assumed and considered workers to have been acclimatized if they had worked in hot weather for over one month, with Nassiri et al., and Ashtekar et al., further considering participants health conditions [28,30,33,41,43,48]. Conversely, El-Shafei et al. and Luque et al., assessed acclimatization *via* questionnaires on participants' knowledge of the 2 to 14 days required for proper acclimatization [37,53]. However, asking workers questions like "Amount of time for body to acclimatize to working in heat" with options ranging from <2 hours to 14 weeks might misrepresent workers' acclimatization status. Knowing the recommended acclimatization duration does not indicate workers are properly acclimatized. Based on ACGIH, ISO 7243, NIOSH, and other guidelines, the recommended acclimatization period for working in hot environments ranges from 7 to 14 days.

Additionally, Langer et al., Yasmeen et al., and Dally et al., operationalized acclimatization based on the CAL/OSHA definition, ISO 7243, and the company's policies, which are consistent with these guidelines [34,39,44].

Twelve studies reported acclimatization for workers [28,30,33,34,37,39,41,43,44,48,53,57]. Four of these assessed agriculture workers, seven assessed construction workers, and one assessed surface miners. Three (construction=1, agriculture=2) studies evaluated acclimatization effectiveness with mixed findings [34,37,39]. One study in Southwest Guatemala among sugarcane workers found that for every 1˚C increase in centered WBGTmean above 30˚C, the expected daily occupational injury rate increased by 3% (95% CI: -6%, 14%), while confirmed dehydration decreased by 15% (95% CI: -87%, 336%) during the acclimatization period [34]. Additionally, Langer et al., reported that approximately 7% of acclimatized California agricultural workers were at higher risk of HRI, with over 50% of unacclimatized workers accounting for recorded HRI incidences [39]. In Egypt, El-Shafei et al., found that a health education intervention improved construction workers' acclimatization knowledge, potentially reducing the reported symptoms severity [37]. Despite acclimatization, occupational injury rates increased with higher temperatures among agricultural workers.

Hydration practices

Hydration practices were reported across industries, detailing drink types, quantity consumed, the availability, and accessibility. Twenty-five studies reported hydration practices; of these, 9 (36%) assessed construction workers [27,30,32,33,37,41,43,44,48], one assessed surface miners and the remaining 60% included agricultural workers. Workers consumed water, electrolyte beverages, soft drinks, energy drinks, tea, or coffee at work [27,30,32-37,39-41,43,44,46-50,52-58]. 10 (45.45%) studies reported that workers consumed sugary beverages and other types of drinks such as energy drinks, alcohol, and beer at work [35,36,40,46,50,52-54,57,58]. These studies were conducted within the agriculture sector, mainly from the USA (n=9; 90%), except one among miners [40]. Most of these drinks were employer-provided, for example, "crew leaders stock the coolers with beer whenever workers have to work longer hours" [52-54]. Agricultural workers often consume beer at work to quench their taste and after work to alleviate sore muscle pains accrued from work and aid sleep [52,56]. These drinks dehydrate. A study that examined Florida agricultural workers reported that workers who drink soda at work are more likely to be dehydrated [50].

Thirteen (52%) studies reported that employers provided accessible water and electrolytes to keep workers hydrated, but only 1 (7.69%) assessed construction workers [33-36,38,39,47,49,50,53-55,57]. With respect to the quality of employer-provided beverages, 3 (13.63%) studies that assessed agriculture (n=2) and construction (n=1) workers reported poor water quality (bad odour or taste) and water temperature (lukewarm) issue [33,46,52]. This resulted in workers either opting for soda or bringing their own water to the worksite.

Six studies quantified water consumption [30,33,35,39,46,58]. Of these two assessed construction workers and reported workers consumed an average of 2.6 litres (L) for entire work shift (7:30 hours) with an increase in average fluid intake ranging from 5.7± 1.1 L to 5.9 ± 1.0 L over the study period [30,33]. It is unclear if the water Ueno et al., reported was employer-provided [30]. A study that assessed El Salvador agricultural workers reported that after implementing the OSHA WRS, the Inland workers' daily average water consumption increased from 5.1 L to 6.3 L [35]. Additionally, 6 studies conducted in the USA reported the frequency and volume of water workers consumed daily [39,46,53,56-58]. To stay hydrated, workers reported drinking water every 15-30 mins or at least once every hour with an estimate of 0.2L/hour [46,53,57]. Overall, workers consume between 2.16L and 2.5 L per workday [46,58].

Only 3 studies examined the effectiveness of hydration in mitigating HRIs and fatalities [30,33,39]. One of these, assessed Saudi Arabian construction workers and reported that researchers' provision of portable cold water instead of employer-provided lukewarm water might have encouraged workers to consume more water to stay hydrated [33]. Another study with Japanese construction workers reported that workers could be dehydrated due to difference between workers' average water intake rate and their water loss [30]. This study also found a low likelihood of workers experiencing hyponatremia due to minimal sugary beverage consumptions [30]. The only study among agricultural workers reported that the Cal/OSHA recommendation of three to four 8-oz cups of water hourly is insufficient for maintaining adequate hydration practices [39]. This study reported that despite the provision and accessibility of high-water quality and increased self-reported water consumption rate, some workers were still dehydrated ($p<0.0001$) [39].

Rest breaks

Nineteen studies reported that workers were permitted to take rest breaks, and the duration can be increased if workers need more breaks to stay hydrated and recover from heat exposure [30-35,37,39,41-44,46,48,49,52-55]. Of these, nine focused on agricultural workers, and ten on construction workers. Seven studies (36.84%) reported that workers were permitted to take two scheduled rest breaks; a 10 - 15 min morning break and a 30-90 min lunch break [35,43,44,46,48,49,53].

Two studies reported the impact of scheduled breaks [35,49]. These studies found that Inland agricultural workers rested 25% of their workday but still spent 42% of their working time exceeding the OSHA's recommended work/rest guidelines. Contrarily, without breaks, Coastland agricultural workers spent 74% of their hours beyond the same guidelines. This OSHA guideline (75% work and 25% rest regimen) is based on the ACGIH, and NIOSH recommendation, a function of WBGT and workload [63].

The effectiveness of rest break programs in reducing HRIs and fatalities is limited. A study reported no association between lunch breaks, other short breaks, and elevated Core Body Temperature (CBT), a risk factor for heat exhaustion and heat stroke if not promptly treated [39].

Cooling practices

Fourteen (38.8%) studies reported different cooling practices, including (i) taking shades, and (ii) using personal cooling gear to prevent heat-related conditions [35,39,41-43,48,49,52-55,57,61-62]. None of these studies were conducted in the mining sector. Six studies (42.85%) evaluated personal cooling gear, including vests, and bandanas, with only two focusing on agricultural workers [41-43,48,61-62]. Eight agriculture studies (57.1%) reported the various cooling strategies available and accessible to workers, including under tree shade (77%-92%) and tents, with only 10% having access to designated rest stations [35,39,49,52-55,57].

The effectiveness of the cooling practices was evaluated both subjectively and objectively. In a qualitative study, an agricultural worker reported that "a person could get dizzy from sweating too much if he/she did not cool off in the shade" [52]. Four construction workers' studies reported that wearing personal cooling gear reduced thermal strain, heart rate, sweating responses, alleviated heat strain, and combat heat stress [41-43,48]. The two studies that assessed cooling gear (cooling vests and bandanas interventions) among agricultural workers were conducted in Florida, USA. These studies reported observed variations in workers' CBT readings exceeding 38.0°C across all four interventions, with the odds of experiencing one or more HRI symptoms decreasing by 80% (OR=0.2, 90% CI: 0.1, 0.8) when wearing both a cooling vest and bandana compared to a control group. Participants in these studies wore the bandana for full shifts and consistently reported feeling very comfortable using it throughout the entire shift of 7 hours and 40 mins [62].

Heat stress training

Nine studies reported on heat stress training and educational interventions, primarily among agricultural workers, except one, with construction workers [35,37,39,52,53,55-57,59]. The construction study found that participants' knowledge and behaviours to prevent exertional heat illness improved significantly after the intervention ($p<0.01$), possibly contributing to the reported mild HRI symptoms [41]. One agricultural study reported continuous education as the key to overcoming cultural resistance to health and enhancing engagement with heat stress prevention [55].

Four USA agriculture studies assessed the effectiveness of various training programs and regulations, including Cal/OSHA, OSHA's heat safety training and app, and HEAT training [39,46,53,59]. One study found that after OSHA training, crew leaders reported better knowledge of HRI symptoms and corrective actions [53]. However, other studies found gaps, including insufficient knowledge despite training, outdated materials, and limited effectiveness of certain programs. Langer et al., reported inadequate HRI risk knowledge, suggesting that the Cal/OSHA HRI training was insufficient [39]. An eastern North Carolina study found that the employer-provided training was outdated and incomplete, featuring the same 3-hours lengthy video to workers annually [46]. The HEAT training in Washington State effectively improved farmworkers' heat-related knowledge [59].

Environmental monitoring

Environmental monitoring is an important intervention for managing heat stress. Studies reported utilizing various parameters, including WBGT, HI, and TWL for monitoring the environment. Twenty-five studies (69.4%) (construction: 11, mining: 3, agriculture: 11) reported measuring WBGT, with six comparing the measured WBGT value to ISO 7243, and two to OSHA guidelines [27-51]. Several studies (n=21) used the ACGIH TLV, two obtained air temperature and relative humidity data from nearby weather Automated Weather (AWN) stations [27-31,33-38,41,42,44-51]. While seven studies used either the National Weather Service (NWS) algorithm, the Rothfusz's HI equation, or the OSHA-NIOSH heat safety tool app to calculate WBGT and HI [33,34,38,39,45,50,51]. Three studies that assessed construction workers (Iran:2, UAE: 1) used TWL [27,31,32]. Two studies used UTCI by following Blazejczyk et al., and Vatani et al., guidelines, while Zare et al. calculated TSI and WBDT [28.29,64-66].

Dillane et al., reported measuring HI using the OSHA-NIOSH heat safety tool app and comparing it with measured WBGT TLV, found that using the app in the agriculture sector is unsuitable because it does not protect workers involved in heavy workloads [45]. One study indicated that construction site workers are at risk for heat-related issues because the measured WBGT (43°C-53.7°C), HSI (70.51%-115.83%), and TWL (117 Watts per meter square (W/M^2)–292 W/M^2) values exceeded the recommended ACGIH TLV [31].

Combining hydration practices, rest breaks, and cooling practices by taking shades (including WRS intervention), three agriculture studies conducted in El Salvador and Nicaragua reported the interventions' effectiveness [35,54,55]. One study found that adequate access to WRS provided workers significant relief from extreme heat stress levels [35]. Another study involving various stakeholders found that the implemented WRS intervention also benefited supervisors' health [55]. Glaser et al., reported that improving access to WRS may prevent kidney injury [54]. The study found that increasing and evenly distributing rest periods, along with better access to shade, water, and electrolyte solutions, significantly reduced the Incident Kidney Injury (IKI) rate and slowed the decline in eGFR from harvest 1 (IKI: 43 of 153; eGFR: -9 mL/min/1.73m^2: 95%CI: -19 to -7) to harvest 2 (IKI: 13 of 183; eGFR: -4mL/min/1.73m^2: 95% CI: -6 to -1) [54].

Discussion

This review identified 6 heat stress interventions studied to mitigate heat-related conditions and promote outdoor workers' health and well-being. The most common interventions were hydration practices, OSHA WRS, and environmental monitoring. Studies with hydration practices and WRS interventions were primarily among agricultural workers, while all the construction and mining studies monitored the work environment. Most interventions reduced HRIs, but none conclusively showed how the intervention protects workers' well-being and QOL using specific well-being constructs.

Current heat stress interventions and effectiveness per intent

Acclimatization

Acclimatization indicated a mixed review in effectively reducing heat stress and HRIs. While acclimatization lowered dehydration rates and injury risks, increased temperatures still increased occupational injury risks. Our findings are consistent with a systematic review on seasonal heat acclimatization among healthy adults, which reported a reduction in core temperature, increased sweat rate, and lowered heart rate [67].

The CDC reported that a good heat illness prevention plan allowing workers to acclimatize properly will reduce HRIs and fatality risks [68]. However, it was difficult to conclude that acclimatization protects workers' well-being because only a few studies reported acclimatization effectiveness, and none examined well-being or QOL constructs. Further studies should explore how acclimatization impacts outdoor workers' well-being.

Hydration practices

Hydration is an important intervention for reducing HRIs and improving workers' overall health and well-being. This review show mixed results regarding drink types and adherence to hydration guidelines, with inconsistent practices which could increase heat stress risk, HRIs, and fatalities, and also compromise workers' well-being and QOL.

The water consumption frequency varies between studies, with agricultural workers consuming water more frequently than construction workers. With 96.7% of agricultural workers drinking water every 15 mins, 70% once every 30 mins, and 21%-78% at least once hourly, only drinking water every 15 mins, aligns with the CDC, NIOSH, and OSHA guidelines [63,69,70]. These guidelines recommend consuming 8 ounces of water every 15-20 mins when working in heat, regardless of feeling thirsty. Also, this review show that workers' daily water intake is below the CDC, NIOSH, and OSHA and Cal/OSHA's recommendation (0.7 L - 0.94 L hourly and about 5.6 L to 7.52 L for 8-hour shifts). Agricultural workers averaged 3.2L, while construction workers consumed 5.7± 1.1 L to 5.9 ± 1.0 L daily [33,46,58]. This is insufficient to keep workers hydrated for 7-12 hours work shifts and could likely be the major contributing factor to the increased dehydration rate, increasing workers vulnerability thus affecting workers' overall health and well-being. Our findings did not support Langer et al., conclusion that the Cal/OSHA hourly water standard is inadequate because our review indicates workers consumed only 0.27 L-0.32 L water hourly [39]. Employers should encourage workers to drink about 0.70 L-0.94 L of water hourly. Further studies are suggested to evaluate the adequacy of the Cal/OSHA standard.

Also, the consumption of electrolyte beverages is highly recommended for replenishing lost electrolytes. Nearly half of the studies, mostly among USA agricultural workers, reported various forms of electrolyte consumption. This is expected because electrolyte imbalances can cause muscle cramps and other health problems [71-73]. While replenishing lost electrolytes reduces heat stress risk levels and supports health, safety, and well-being, further studies are needed to quantify its effects on outdoor workers.

With agricultural workers having access to drinks, including soda, sugary beverages, energy drinks, and beer, this can negatively impact safety and health, leading to dehydration and increasing HRIs risk. Studies show that such drinks, especially energy drinks promote dehydration and significantly increase HRI risks [74]. Also consuming soft drinks during and after exercising in the heat can elevate AKI biomarkers [75].

More than half workers arrived at work dehydrated, which increased over the workday [33,46,50]. This could be due to alcohol consumption or inadequate preparation the night before, as described in our previous study, which is consistent with another study [76]. The university of Illinois urbana-campaign division of research safety found that alcohol consumption within 24 hours of working in the heat can elevate dehydration risk and heat illness [77]. Future studies should explore the additional reasons agricultural and construction workers mostly arrive at work dehydrated.

The only mining study that reported workers consumed various beverages, did not specify the consumption rate, frequency, and sources [40]. While the Mine Safety and Health Administration covers the mining industry heat stress (30 CFR Part 50.20), further studies should assess the sugary beverage consumption rate and determine whether miners receive adequate and accessible water and electrolytes [78].

Rest and shade

None of the studies examined the relationship between rest breaks and HRIs or its impact on well-being. However, scheduled and permitted rest breaks without considering WBGT values may not effectively reduce heat stress risk or protect workers' well-being. The duration and frequency of rest breaks should mainly depend on multiple factors, including WBGT values. The reported WBGT values ranged from 9.7˚C to 53.7°C. According to NIOSH and ACGIH TLV, workers engaged in moderate work where WBGT value is 29˚C should follow a 75% work/25% rest regime (i.e., 45-mins work/15-mins rest) in a shaded cool area [70]. However, some studies found that agricultural workers often exceeded this limit, spending over 40% of their working time beyond the regime. Therefore, we recommend that employers consider monitoring the environment throughout the entire shift in determining appropriate rest break durations. Further research is needed to evaluate the effectiveness of work/rest breaks per environmental monitoring.

With regards to taking shade, the reviewed agricultural studies indicate that taking shade under trees might not effectively reduce HRIs risks, as workers could still be exposed to sunlight. A study assessing Australian Health and Safety Professionals (HSP) found a correlation between HRIs and working in the sun without shade [79]. Taking breaks in cool areas after working in the heat is an important preventive measure to protect workers, as recommended by several agencies.

Cooling practices

The cooling interventions were mainly evaluated among construction workers. Wearing an anti-heat stress uniform, vest, cooling gear, and bandana potentially reduced CBT, sweat loss, HR, perceptual strain, and combat heat stress among workers. This is consistent with a meta-analysis that reported that cooling vests improve perceptual responses and reduce CBT and HR [80]. However, the effectiveness of these interventions except bandanas, remains uncertain, as they were typically worn for shorter periods (15-220 mins), mostly rest breaks rather than full work shifts. These durations are shorter than the typical 7:40-12:00 hours outdoor workers' work shifts. Since occupational heat exposure is mostly during work and not rest breaks, further research is needed to evaluate the effectiveness and feasibility of wearing cooling interventions, excluding bandanas throughout full work shifts, in preventing heat stress, reducing HRIs, and protecting workers' well-being.

A systematic review concluded that combining cooling gears with rest cycles might be the most effective method to reduce HRI [13]. We suggest future studies evaluate the effect of these over entire shifts to better understand their effectiveness. Overall, the effectiveness of cooling interventions remains inconclusive, as little is known about their use throughout entire work shifts.

Heat stress training

Heat stress training varied in effectiveness, with some studies showing improved knowledge and preventive behaviors, while others reported outdated or ineffective training. For example, Langer et al., reported that >15% of California agricultural workers correctly answered questions about HRI risks [39]. This knowledge gap could be due to several factors, including the type and adequacy of training provided, poor dissemination, training frequency, and duration, or employers not adhering to the Cal/OSHA standard. Our suggested reasons are consistent with a study of Australian HSPs, which found that only 42% of 307 participants reported the availability of adequate heat training in the workplaces they visited/managed [79]. Providing accurate and adequate heat stress training is essential, as OSHA reported that training can effectively reduce workplace injuries, illnesses, and fatalities [81]. However, further research is needed to evaluate the accuracy of training provided to outdoor workers.

Environmental monitoring

Environmental monitoring is essential for assessing heat stress, but it was not directly evaluated per workers' well-being and QOL. The reported WBGT values vary across sectors (agriculture: 9.7˚C to 37.8˚C; construction: 21.7°C to 53.7°C; mining: 23°C to 28°C), indicating different heat stress levels ranging from low to very high depending on other factors including acclimatization, workload, etc.

However, regardless of the guidelines used (ACGIH or ISO 7243), most WBGT values exceeded the recommended limits, indicating the potential of WBGT values impacting workers' health and well-being if precautionary actions are not implemented [82,83]. A systematic review found a 2.1% increase in cardiovascular disease-related fatalities and a 0.5% increase in related illnesses for every 1°C rise above reference temperatures [84]. Additionally, a heat wave study in Moscow found an increased risk of 2.29 (95% CI: 2.18-2.40) for ischemic heart disease fatalities, one of the leading causes of death among USA construction workers aged 25 and older in 2020 [85,86]. Thus, precautionary actions, including at least 40 mins rest breaks every hour when temperatures reach 29.4°C-31.1°C per OSHA outdoor WBGT calculator and following the NISOH work/rest schedule are strongly recommended [87,88]. Further studies should explore how WBGT values impact outdoor workers' QOL using specific well-being constructs.

Conclusion

This review identified hydration practices, WRS, environmental monitoring, acclimatization, heat stress training, and cooling interventions as heat stress interventions designed to reduce heat stress and heat-related conditions among outdoor workers. However, no single intervention is sufficient to reduce HRIs and protect workers' well-being. The NIOSH, OSHA, and Cal/OSHA recommended hydration guidelines may adequately keep workers hydrated throughout the work shift, provided employers encourage workers to drink 8 ounces of water every 15-20 mins and provide sufficient electrolytes.

This is the first study to evaluate real-world occupational heat stress exposure and current interventions among outdoor workers. This comprehensive assessment highlights the need for integrated interventions to protect workers from heat stress and emphasizes that effectively managing heat stress requires a multifaceted approach, which may have a significant impact on outdoor workers' well-being and QOL. However, future research should evaluate how this multifaceted approach will impact outdoor workers' well-being and QOL.

Acknowledgment

This review highlights the known implemented heat stress interventions' effectiveness in mitigating heat stress, emphasizing the need for a comprehensive approach with the implementation of multiple interventions to protect vulnerable outdoor workers' health and well-being.

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Ethical Considerations

The Institutional Review Board of the University of Texas Health Science Center at Houston approved the study. No informed consent is required.

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