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REVIEW ARTICLE

Risk Factors and Heat Reduction Intervention among Outdoor Workers: A Narrative Review

Mei Ching Lim[1], *Khamisah Awang Lukman[1,2], Nelbon Giloi[1], Mohammad Saffree Jeffree[1], Saihpudin @ Sahipudin Saupin[1], Pravina Deligannu[1]

[1] Department of Public Health Medicine, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah, Jalan UMS, Kota Kinabalu, 88400, Sabah, Malaysia.
[2] Centre for Occupational Safety & Health, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia

ABSTRACT

With the ongoing climate change, heat waves are anticipated to become more frequent and intense. Hence, heat-reduction interventions are essential, particularly for outdoor workers. Although numerous studies focused on heat stress among outdoor workers, there is little evidence of a comprehensive heat prevention program. This review relied on secondary sources from various sources and databases, including ProQuest(361), Springerlink(398), ScienceDirect(698), and Google Scholar (54). This review aims to identify the risk factors of heat stress and appraise the various heat reduction strategies. The risk factors identified include environmental elements, occupational factors, and individual characteristics. As no one method suits all occupations, a holistic heat prevention program that incorporates effective interventions is crucial. This includes an adequate water-rest cycle, heat-related awareness training, and individualised cooling techniques (bandanna, cooling vest or uniform). This acceptable, affordable, accessible, and sustainable program will improve the workers' comfort while lowering the incidence of heat-related illnesses and mortality.

Keywords: Heat prevention program; Heat reduction interventions; Heat stress; Outdoor workers; Risk Factors

Corresponding Author:
Khamisah Awang Lukman,
Email: khamisah@ums.edu.my
Tel: +608-8320000

INTRODUCTION

According to a 20-year study by Zhao et al. (2021), over five million people die each year from extreme temperatures globally, with heat-related mortality accounting for an estimated 491,000 of those deaths, and yet, the number of heat-related deaths is still rising (1). Over recent years, heat waves have become one of the leading causes of global weather-related mortality and diseases(2), especially with the continuous climate change and effects of urban heat islands (3). The National Institute of Occupational Safety and Health (NIOSH) and Centers for Disease Control and Prevention (CDC) have defined heat stress as the accumulation of metabolic heat in addition to environmental heat gained from the surroundings, including work settings, but deducting the heat lost from the body to the environment (4).

Weather-associated heat exposures constitute a serious health concern due to the uprising and intensity of heat waves (2, 5). Besides, occupational health and safety concerns are on the rise, particularly among vulnerable outdoor working populations in tropical and subtropical countries (5-9). The risk of heat stress is relatively high for workers who spend long hours under the sun, such as members of the armed forces, firefighters, police, agricultural workers, construction workers, municipal workers, and miners, (7,9-12). These workers not only have the disadvantages of minimal indoor environments with air conditioning and adequate ventilation but also experiences lengthy and extreme heat exposures from outdoor settings, especially when performing manual labour tasks. Even though heat stress is a widely known occupational risk that is accountable for heat-related diseases and injuries every year, many cases may not be reported due to a lack of awareness, poor commitment from employers, inadequate surveillance, and misdiagnosis because their clinical signs and symptoms were similar to those of other illnesses (13-16).

The human body adapts to the thermal surroundings. It maintains the internal core body temperatures between a restricted range of 36°C to 38°C through behavioural or voluntary responses and physiological autonomic or involuntary responses (17). Individuals' behavioural or voluntary responses commonly comprise how they reduce or avoid heat stress by adjusting their body's surrounding environment, such as wearing light and comfortable clothes with protective headgear in outdoor occupations or by making modifications in their work environments, like adding or increasing shaded areas (18).

On the other hand, physiological autonomic responses are the body's adaptation to excessive heat temperature by adjusting to heat exchange via convection (transfer of heat to the air surrounding the skin) and radiation (18). The responses include peripheral vasodilation to intensify heat conduction and increase sweat secretions for evaporative cooling, allowing the body to increase the rate of heat loss to compensate for heat stress and balance the heat strain (18).

The thermoregulation mechanism in the body is essential to ensure that the body's core temperature is retained closely around 37°C at rest or in comfortable surroundings (18). Disruptions to the thermoregulation will result in acute heat disorders, which may vary from straightforward postural heat fainting or syncope to more complex and life-threatening heat stroke (19).

A systematic review by Xiang et al. (2014) revealed that the prevalence of heat stress-related symptoms varies from 11.8% to 63.7% among outdoor workers such as in agricultural, construction and mine industries (16). Higher heat-related mortality was reported among agricultural (20,21), construction workers (20,21), and mining workers (21). Besides having a greater risk of kidney injury (22,23), exhaustion (24), and psychological stress (24) when exposed to prolonged heat, heat-related illnesses (HRIs) also intensify the risk of occupational accidents and injuries, brought on by misted-up safety glasses, fatigue, light-headedness, muscle weaknesses, and wet slippery hands (4, 24, 25).

The long-term effects of heat exposure will impact the individual's social well-being, family income, labour productivity, and the nation's economy (15,26-29). The high ambient temperatures have been linked to a 5.3% decline in outdoor manual labour output around the world (30). In addition, the International Labour Organization (ILO) has forecasted that the growing phenomenon of heat stress caused by climate change, will result in a worldwide productivity loss of 80 million full-time employment by 2030, primarily in agriculture and construction-related labour (31). According to the study by Kjellstrom (2016) (32), heat-exposed industries in Southeast Asia risk losing between 15 and 20% of their annual work hours, which may double in 2050 because of climate change. Furthermore, 63.5% of the Chinese construction workers in the study by Han et al. (2021), claimed that extremely hot weather reduced their work productivity (33).

Furthermore, studies have highlighted some of the heat-adaptation strategies taken by the workers to protect themselves from HRIs including wearing caps, hats or wide-brimmed hats (34-36), loose and light-coloured clothing (35,37,38), regular fluid intake, (34,37-39), taking frequent breaks (37,38), active participation in heat awareness and education training (37,40), heat acclimatization (34,39,41), personal cooling garments (39), reduced physically demanding task by using mechanical equipment (37) and cooling systems (37).

While there are many studies on heat stress intervention among outdoor workers, especially firefighters and agricultural and construction workers, there is limited evidence of a complete and sustainable heat prevention program among these or other susceptible workers like municipal and landscape workers. Hence, this review aims to determine the risk factors of heat stress and appraise the various heat reduction interventions that can be adapted as a comprehensive heat control and prevention program for outdoor workers to reduce heat-induced morbidity and mortality in occupational settings.

METHODOLOGY

Search approach

This literature review relied on secondary sources from electronic databases, including ProQuest, Springerlink, ScienceDirect, and Google Scholar. Relevant articles to this review were also manually identified from established websites of international agencies related to occupational health, environmental health and climate change like Centers for Disease Control and Prevention (CDC), World Health Organization (WHO), International Labor Organization (ILO), Occupational Safety and Health Administration (OSHA), Canadian Centre for Occupational Health and Safety (CCOHS), Health, Safety and Environment (HSE) and Safety Work Australia (SWA). The terms used in the search include "heat coping mechanism", "heat-related illnesses", "heat-related productivity loss", "heat stress", "heat strain", "risk factors of heat stress", "cooling intervention", "heat prevention measures", and "outdoor workers".

Inclusion and exclusion criteria.

The articles selected for this review fulfilled the following criteria:

- Written in English. Studies published in other languages were excluded.
- Published in journals or in databases as well as updated on websites from 2011 to September 2022. The authors only searched for articles published after 2011 to deliver a better outline of the latest information and findings of the topic being reviewed. This helped to avoid duplicating descriptions of studies whose significance has waned over time.
- Limited to studies involving the human population in outdoor working environments or simulated outdoor

activities in climate-controlled rooms.
- Exercise trials in climate-controlled rooms or research involving indoor working groups were omitted since it would be challenging to extrapolate these findings to the intended population of outdoor workers.
- Articles with no full text, conference abstracts, commentaries and letters to editors were excluded.

A total of 1544 articles were identified from the databases, but 168 duplicated articles were removed. Another 797 articles were removed after screening the titles which were not relevant to this review. The articles' abstracts, keywords and summaries were assessed thoroughly to determine their significance in this review. 497 articles were further omitted after reading through the abstracts. Furthermore, the reference lists of relevant articles were also reviewed to ascertain further articles for inclusion. Hence, 93 additional articles from Google Scholars, e-books and other web pages were included. A total of 87 full-text articles that met the inclusion criteria were finally selected for this review and the selection process is summarized in Figure 1.

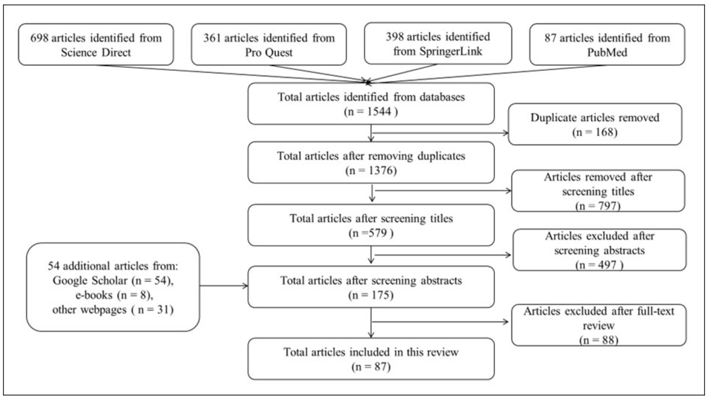

Figure 1 : Summary of the methods used to select the articles for this review.

RESULTS

Heat-related policies, regulations and guidelines

Despite numerous papers published highlighting the various risk factors, whether personal, occupational, or environmental, there is very limited specific heat-related legislation or regulation worldwide, particularly for outdoor workers who are the most susceptible group to experience HRIs. The United States' Occupational Safety and Health Administration (OSHA), National Institute of Occupational Safety and Health (NIOSH) as well as the American Conference of Governmental Industrial Hygienists (ACGIH), have published a number of guidelines and manuals as reference for industry, government and also the public, emphasizing on heat preventive measures (43). Likewise, nations like Australia, Canada, the United Kingdom, as well as Malaysia, has developed heat-related work action plans, guidelines and standards to reduce occupational heat-related morbidity and mortality (44-48).

The United States has no federal heat regulations, but only three states, namely Washington (only outdoor workers) (49), Minnesota (only indoor workers) (50) and California (51), have established regulations to protect their workers (52). Other nations including those in China, Thailand, Africa (Gabon, Mozambique and Cameroon), Central and South America (Costa Rica and Brazil), Europe (Belgium, Cyprus, Germany, Hungary, Latvia, Montenegro, Slovenia and Spain), as well as in the Middle East (Qatar, Kuwait, Bahrain, Oman, United Arab Emirates and Saudi Arabia), follow suit in enacting heat regulations (52-55). These heat regulations mostly specify safety and protective measures like maximum working temperature, reduction in work hours on hot days, adequate ventilation, provision of drinking water, appropriate working attire, training courses, free medical check-ups as well as penalties if fail to comply to the regulations (49-55).

Since 2012, China has been implementing the Administrative Measures on Heatstroke Prevention Strategy (AMHP) 2012, which outlines employers' obligations to provide protective measures to the workers, limiting outdoor working hours and providing heat subsidies (53). A recent evaluation study conducted in Guangzhou city revealed a significant

Table I : Risk Factors of Heat Stress

Risk Factors Of Heat Stress		
(i) Environmental Factors	**(ii) Work-related Factors**	**(iii) Personal Factors**
• Air temperature • Radiant temperature • Air velocity • Air humidity	• Acclimatization • Hydration at work • Manual work tasks • Personal Protective Equipment (PPE) • Dark-coloured, tight-fitting clothing	• Age < 25 or > 60 • Gender • Overweight/Obese • Physical fitness • Water consumption, • Co-morbids (diabetes, hypertension) • Medication (*diuretics, anti-depressants, anti- histamines, and anti-psychotics*) • Supplements • Alcohol & sugar-content drinks

reduction in the risk of extreme heat-related occupational injuries and insurance claims since the policy was enforced (53). On the other hand, although Thailand's occupational exposure to heat and hot environment standard has been in force since 1976 with revision made in 2006, not all workplaces are compliant with it, exposing susceptible workers to the risk of HRI (54).

Risk Factors of Heat-Related Illnesses

It is crucial for outdoor workers to be aware of factors predisposing them to risk of heat-related illness, which could be divided into environmental, work-related, and personal factors, as summarised in Table I.

i- Environmental Factors

The body's heat balance is influenced by four key environmental components: air temperature, radiant temperature, air velocity or wind and air humidity, and other factors like clothing and metabolic rate (8). OSHA defines high heat when the air temperature exceeds 35^{o}C (44). The risk of heat-related illnesses rises significantly when the ambient temperature is high, or other relevant environmental elements become more intense (4,24,25). Wet Bulb Globe Index (WBGT), which is derived from air temperature, radiant temperature, wind speed and air humidity, had been used to quantify the association between environmental factors and human physiological responses (56).

In a multi-country occupational heat stress research involving workers in the agriculture, construction, and tourism sectors, significant associations between WBGT and skin body temperature were observed for agricultural workers ($p<0.001$), construction workers ($p<0.001$), and tourism workers ($p=0.032$) (57). WBGT and the core body temperature of agricultural workers in the same study were not associated. However, there was a significant relationship between WBGT and the core body temperature of construction workers ($p = 0.01$) and workers in the tourism sectors ($p = 0.017$) (57). Similarly, a study conducted by Vega-Arroyo et al. (2019) among migrant farm workers in California during summer months, reported that a higher WBGT was significantly associated with higher core body temperatures (p-value <0.01) (35).

Besides, in the research among the date harvesters in palm groves in Jiroft, Iran, WBGT and wet bulb temperature which measures the relative humidity of the air, were significantly correlated with tympanic temperature while dry bulb temperature was significantly correlated with the heart rate ($p<0.001$) (58). Furthermore, a study by Grimbuhler and Viel (2021) conducted among Vineyard workers in Southern France, found a significant association between the dry bulb temperature and an increase in the mean heart rate (p-value=0.03) (59).

ii- Work Factors

CDC defined heat adaptation or acclimatization as "the beneficial physiological adjustments that ensue following repeated exposure to a hot environment", which is best accomplished by progressively increasing work hours in hot weather over seven to fourteen days, as well as cooling down and rehydrating completely in between shifts (4,60). Based on a study conducted by Park et al. (2017), 46.8% of outdoor workers in Korea who received compensation for occupational heat-related diseases were not acclimatised (61). Workers in two qualitative studies also perceived that unacclimatized workers posed a greater risk of heat-related illnesses, with worsening symptoms especially when they were unable to recover adequately before the next heat exposure (34, 62).

Besides, internal body heat further aggravates the heat stress caused by manual and strenuous work tasks as well as the long duration at work (16). The research conducted by Grimbuhler and Viel (2021) among vineyard workers, described that longer work hours was associated with a higher cardiac strain ($p<0.05$) (59). In a separate study involving farmworkers, Vega-Arroyo et al. (2019) reported that an increase in physical work activities was significantly associated with an increase in core body temperature ($p=0.001$) (35). According to a study by Mac et al. (2019), fernery workers had 12% higher odds of attaining or surpassing the 38^{o}C of core body temperature for every 100 kilocalories of energy exerted (63). Agricultural workers in the higher workload category had almost two times higher odds of experiencing acute kidney injury (AKI) (OR = 1.92, 95% CI 1.05 – 3.51) (64). Additionally, the body will experience higher stress from strenuous physical activities due to an increase in heart and respiratory rates, blood flow, and perspiration (65).

Longer work experiences were also significantly associated with a reduced likelihood of heat-related illnesses among construction workers ($p<0.01$, OR=0.98, 95%CI 0.954–0.999) (66). Piece-rate work procedures allow workers the flexibility to adjust their work effort during various heat exposure levels. Nevertheless, workers under the piece-rate payment schemes were motivated to work more diligently and quickly to obtain higher incentives, which predisposes them to three (OR=3.0; 95% CI, 1.44-6.34) (64) to six times (OR: 6.20; 95% CI: 1.11–34.54) (67) more likely to experience heat-related illnesses.

Furthermore, based on the qualitative research among Australian workers exposed to hot environments, limitations of workers' autonomy in decision-making were also perceived as a potential contributing factor for heat-related illnesses (34). Workers were indirectly under tremendous pressure to continue working while under-rested, amidst an alarmingly hot environment that exposes them to a higher risk for heat-related illnesses (34). Inadequate or restricted access to basic sanitation facilities at workplaces including toilets, also influenced the workers' hydration status as they would consume less water, which puts them not only at higher risk for dehydration and heat stress but also genitourinary infections (34, 68).

iii- Personal Protective Equipment (PPE)

Furthermore, the risks of heat-related illnesses are also influenced by the types of protective clothing and characteristics of personal protective equipment (PPE) (4,69, 71-74). Wearing water-resistant PPE, which covers the whole body and face, restricts air movement and decreases the cooling effects of sweating (4,69). Due to this, the body produces far less heat to release into the environment, increasing the heat load on the body in the process (45,70). In two separate studies conducted among Australian firefighters (71), and health and safety personnel (72), 38% and 52% of the respondents, respectively, claimed that wearing PPE at work increased body temperature and worsened heat-induced fatigue, increasing the risk of heat-related illnesses in the workers.

Besides that, a study by Ricco et al. (2020), reported that the likelihood of heat-related illnesses was nearly nine times higher for pesticide workers who wore insulating PPE while performing their tasks (p=0.012, OR=8.85, 95% CI 1.88 – 41.58) (73). Additionally, unsuitable working attire, such as dark-coloured or tight-fitting clothing, might raise the risk of heat-related illness (4,74).

iv- Personal Factors

Personal risk factors may increase an individual's susceptibility to developing heat-related illnesses. Older workers who are more likely to have chronic medical conditions were noted to be more vulnerable to heat stress due to poor blood circulation, decreased sweat rates, an inadequate heat-compensating mechanism, and work burden (26,75,76). Nevertheless, studies have revealed that younger workers, those under the age of 25 years, were more vulnerable to heat-related illnesses or injuries since they frequently perform more manual challenging tasks in hot environments (67,77,78).

Women are more cautious in taking preventative measures for heat stress and are more likely to report heat-related symptoms earlier than men (79). In a study by Mutic et al. (2017), female farmworkers were noted to have three times higher odds of experiencing at least three heat-related symptoms compared to male farmworkers (OR = 2.67; 95% CI 1.10–6.50) (80). Besides that, women had a higher proportion of heat intolerance than men, as women had higher body fat and lower aerobic power (81,82). In a study by Mac et al. (2019), female fernery workers were more than five times more likely to have core body temperatures of at least 38°C compared to their male counterparts (OR: 5.4, 95% CI: 1.03–18.30) (63). Besides, a separate study of pesticide applicators, also reported that female workers were 3.7 times more likely to experience heat-related illnesses than their male counterparts (73). Nevertheless, another study highlighted that lower heat-related illnesses are reported among women as they can endure a hot and humid environment better than men due to their smaller anthropometric features (83). One study of vineyard workers revealed that the male gender was associated with increased mean skin temperature during work compared to female workers ($p<0.05$) (59). Furthermore, male workers were more likely than female workers to have injuries due to heat stress as they were more likely to perform intensely demanding duties and work in hostile climates, which puts them at greater risk of injury in hot environments (77,78,84).

Special consideration should also be given to overweight or obese workers as they tend to generate more heat per unit of surface area compared to lean workers (26,85). Subcutaneous fat may prevent heat loss and affect the body's capacity for thermoregulation (85). Overweight workers also experienced more significant levels of cardiac strain (86), heat exhaustion (87) and approximately 3.5 times more frequently suffer from fatal heatstroke (88). According to two separate studies, military personnel with BMI ≥30 kg/m^2 were more likely to experience mild to severe heat-related illnesses (89,90) .

Furthermore, a worker's physical fitness is another main contributing factor in influencing a worker's ability to perform work under heat stress (44,45). Workers can safely perform various job tasks when they are at a good fitness level. A fit individual is considered to have a less physiological strain, a more efficient sweating mechanism and a lower core body temperature, which denotes less heat retention (91,92). Physical activities at work will increase additional strain on the body by increasing the heart and respiration rate, blood flow, and perspiration (11). These findings were supported by Nelson et al. (2018) study, which indicated that military personnel with poor physical fitness, had a significantly increased risk of heat-related illnesses (90).

The body loses a substantial amount of water through perspiration in warm and hot environments (93). At the same time, sweating assists in lowering the core body temperature. Nevertheless, the body needs to replenish the water lost in order to prevent dehydration and eat-related illnesses (94,95). The body tends to overheat with inadequate water consumption (93). Hence, CDC recommends drinking enough water (approximately 500mls every 30 minutes throughout the complete work shift) is crucial to stay hydrated (95).

Individuals with pre-existing chronic conditions like diabetes, high blood pressure, cardiovascular or pulmonary illnesses, and individuals on long-term medication may pose a higher risk of heat-related illnesses and heat stress. These conditions cause them to experience physiological deterioration in the thermoregulation of their body core temperature (4,88,96).

Many groups of medications, either prescribed or over the counter, consumed by workers with underlying chronic diseases and recreational or illicit drugs may predispose workers to heat-related illnesses and other severe medical conditions (19,97). The heat-interacting medications include diuretics, anti-depressants, antihistamines, and anti-psychotics (98,99). The medications and drugs can interfere with the normal thermoregulatory functions, causing, among others, a reduction in sweat rate, changes in renal functions, cardiac output and peripheral vasodilation (19,99,100). Studies by Nelson et al. (2017 & 2018) revealed that personnel on non-steroidal anti-inflammatory drugs (NSAIDs) (OR=1.31; 95% CI: 1.05 – 1.64), opioids (OR=1.92; 95% CI: 1.08 – 3.41), stimulants (OR=5.68; 95% CI: 1.41 – 22.9), and antipsychotics (OR = 3.25, 95% CI: 1.33, 7.90) were associated with higher odds of HRI (90,101).

Besides that, alcohol, carbonated drinks, sodas, and drinks containing caffeine and sugar like coffee and tea, increase acute urine output, which may lead to further dehydration (94,95). Dehydration increases a worker's vulnerability to heat-related illness and may affect their work performance (95). According to the study by Boonruksa et al. (2020), sugarcane cutters with long exposure to hot an environment were noted to be dehydrated and significant physiological changes including heart rate, body temperature, and systolic blood pressure were documented throughout the work shift (9). Additionally, sugarcane farmers who drank approximately 3.1 to 5.0 litres of water daily had a 70% lower risk of heat-related illnesses (102).

Heat Reduction Intervention

Heat stress not only increases the likelihood of heat-related illnesses but also intensifies the risk of accidental occupational injuries, which may result in decreased work productivity, long-term absenteeism, or early retirement (25,31,84). Hence, heat reduction intervention is necessary to reduce heat-related morbidity and mortality, especially among outdoor workers. Over the years, various research has been conducted among outdoor workers to determine the influence of cooling approaches in reducing the negative health impacts or physiological heat strain as a consequence of heat stress in occupational settings.

i- Heat Stress Awareness Program

Heat stress awareness program (HSAP) was implemented since 2011 among municipal outdoor workers in Texas city after strong data indicated that these workers were at risk for heat stress and HRI (103). Workers who perform moderate to severe demanding physical labour in hot humid environments were recruited in HSAP, which comprised of HRI awareness training, acclimatization schedules, work-rest procedures, water drinking habits, medical surveillance, heat-related emergency procedures, and the introduction of first aid protocols for workers (103). The study by McCarthy et al. (2019), which retrospectively evaluated the compensation claims of HRI before and after the introduction of HSAP, reported that the program managed to reduce the number of HRI cases and decreased median compensation expenditures by half (103).

However, a separate study conducted by Butler-Dawson et al. (2019) among Guatemalan sugarcane harvesters, yielded negative outcomes (104). The study focused on expanded heat-related educational programs, emphasizing face-to-face interactions, posters, pocket urine colour charts and wellness rewards for workers who were able to maintain adequate hydration status (104). Despite having good hydration levels, the workers had higher incidences of acute kidney injury across shifts (104).

ii- Water, Rest and Shade (WRS)

The United States Occupational Safety and Health Administration (OSHA) initiated a Heat Illness prevention campaign in 2011, focusing on increasing awareness of the hazards of outdoor work in hot environments and encouraging workers to take precautionary measures (44). The main safety recommendations are a simple "Water, Rest, Shade (WRS)" message, emphasizing water consumption and adequate rest in the shade (44). A longitudinal study was conducted among agricultural workers based on a modified WRS concept, in which the workers wore 3-litre backpacks filled with water to drink while working, with recommendations of 15 minutes break every hour in a portable canopy shade (105). The workers claimed to have more regular water intake, experience fewer heat-related symptoms post-intervention, and enhance work satisfaction and productivity (105). Other studies conducted among sugar cane workers reported a decreased effect of heat stress on acute kidney injury programs (106,107) and improvement in the electrolyte solution and water intake (107).

iii- Work/rest ratio

'Planned breaks' were introduced in the study by Ioannou et al. (2021), which involved agricultural workers in Cyprus and Qatar, as well as construction workers in Qatar and Spain (57). Agricultural workers in Cyprus were allocated 90 seconds of breaks every half an hour throughout the workday (0600 to 1400) while construction workers in Spain were given two seven-minute breaks precisely at 1230 and 1630 (57). Both agricultural and construction workers in Qatar were allocated 10 minutes of break time every 50 minutes from 0600 to 1100, and they were encouraged to rest and hydrate in the shade (57). Only the study among the construction workers in Qatar indicated significant differences (p< 0.001) in the reduction of skin temperature, heart rate and labour effort while neither of the other three studies reported any significant reduction in the physiological parameters and labour effort (57).

iv- Ice slurry

Construction workers in Spain have also been introduced to an ice slurry strategy in which they were requested to consume 300ml of crushed ice every hour (57). There was a significant difference in the skin temperature (p=0.034) but no significant difference was noted in the core temperature, heart rate or labour effort (57).

v- Combination of work/rest ratio and ice slurry

Three different heat reduction measures were applied among the workers in the tourism industry in Greece (57). The tourism workers were given either 90 seconds of a planned break for every 30 min continuous work; ice slurries (3.5 mL per kilogram of body mass) every hour of continuous work, or a combination of a two-minute planned break and ice slurry ingestion (2.4g per kilogram body mass) after every hour of continuous work (57). Nevertheless, no significant difference was noted in the physiological parameters or labour effort post intervention in all three measures (57).

vi- Cooling Jackets or Vests

Specially designed hybrid cooling vests (HCV) featuring phase change materials (PCMs) and ventilation fans were created for construction workers in the studies by Yi et al., (2017) (92) and Chan et al. (2016) (108). The workers considered the HCV acceptable, comfortable and convenient, with a notable 91% of the workers preferring to use the HCV as a cooling measure while at rest (108). The outcome from the studies proved the effectiveness of the HCV, demonstrated by the noteworthy lower heat sensation (92,108), reduced rate of perceived exertion (RPE) (108), decreased core body temperature (92), lower heart rate (92,108) and perceived strain index when wearing HCV (108).

Furthermore, a study by Ashtekar et al. (2019) involved a personal cooling garment (PCG) which is a jacket-like enclosure liquid cooling system (109). This system comprises four major elements: (i) a vest covering the back and chest, (ii) a heat exchanger polyvinyl silicon tube line, (iii) backpack container filled with chilled-water, and (iv) a small battery-operated motor pump (109). Workers' physiological responses in circulatory, thermal and subjective strain were lower when wearing the PCG system (109). Workers claimed to be able to comfortably and conveniently carry out their typical work tasks without affecting the quality of their work (109).

Cooling vest, which was used among the firefighters in the study by Hemmatjo et al., (2017), was also noted to be effective in reducing physiological responses as well as improving cognitive functions (cognitive response and reaction time) during firefighting procedures (110). The cooling vest utilised during recovery significantly enhanced thermoregulatory and cardiovascular strain recovery by lowering the body's core temperature and heart rate (110).

Even though cooling vests or jackets can be convenient and effective in reducing thermal strain, there was mixed feedback on the practicability of wearing them while working. This is because the jackets and vests can also be uncomfortable and weighty when the ice or cooling material melts after a short time and the need to replace the ice or cooling material (109,111,112).

vii- Cooling Bandana

According to a qualitative study by Chicas et al. (2021), participants who were agricultural workers accepted and approved the use of bandana as a cooling 'tool' during work because the bandana was simple to use, did not require much effort, and did not disrupt their daily routine (111). The workers claimed the bandana kept them cool while working, although no documented parameters were collected post-intervention (111).

viii- Anti-Heat Stress Clothing or Uniform

Three studies focused on the production of heat-relieving uniforms for construction workers, highlighting the use of textiles with better heat-and-moisture-transporting properties as well as ergonomic clothing design for increased comfort, mobility and safety at work. An anti-heat stress work uniform consisting of a Coolmax collar shirt in light blue and Nanotex Dry inside fabric pants in khaki colour was invented, with additional design features, like loose fit, raglan sleeves, front or back seam, and semi-elastic adjustable waist size (108). The new uniform was more comfortable with dryer skin sensation (108). The additional ergonomic clothing factors allow more flexible body movement and enhance work performance by more than 35% (108).

On the other hand, the anti-heat stress uniform by Yang (2017) consists of a short-sleeved shirt (65% cotton, 35% polyester) and long pants (100% cotton) (113). The new uniform was observed to keep the workers' dryers more comfortable, with minimal work performance interruption (113). The workers eventually developed a higher level of heat tolerance, which decreased their perception of heat strain (113). A separate study among a group of construction workers involving an anti-heat stress uniform (a polo T-shirt and a pair of trousers) with added hybrid cooling vest also reported a significant reduction in physiological and perceptual strain in the cooling condition during rest and the subsequent work after cooling (112).

Furthermore, 'ventilated garments (short-sleeved shirts with integrated electric fan)' as well as 'evaporative clothing (breathable, lightweight work shirt and trousers)' were introduced to workers in Cyprus and Qatar, respectively (57). While there was no significant difference in the core body temperature, heart rate and labour effort among the agricultural and construction workers in the study, there was a significant decrease in skin temperature among the agricultural workers in Cyprus (57).

ix- Cooling Gel Patch

The cooling interventions introduced to firefighters include cooling gel patch containing menthol (110) and head-cooling gel pack in helmets (114). Nevertheless, post-intervention, no significant differences were observed in the basal temperature, pulse rate, physiological strain or perceptual parameters.

x- Cold water immersion of the forearm or lower body and Water Dousing

Cold water immersion of the forearm (114,115) and lower body (116) were also initiated as cooling interventions among firefighters. While no significant difference was noted in the heart rate (114,115), rated perceived exertion (RPE) (116), the forearm and body immersion cooling techniques were found to lower the perceived strain (114) and better rate of reducing the core temperature (114-116).

Additionally, previous studies have indicated that cooling the head and neck during high body temperature levels will significantly decrease heat-related tiredness and cardiovascular strain (117) and reduce skin temperature (118,119).

xi- Nutritional intervention

Imbalances in water and electrolytes due to profuse sweating, have been linked to increasing the risk of heat-related illnesses (120). Therefore, electrolytes and nutritional replenishment while performing physically demanding tasks that cause significant perspiration, may also be recommended as part of heat reduction intervention. Twenty-one male firefighters took part in a randomized, repeated measures trial conducted by Horn et al. (2011), to assess the effectiveness of applying an enhanced cooling nutritional intervention in decreasing physiological heat strain (121). The firefighters were requested to perform repeated two 18-minutes firefighting training drills with a 48-hour gap between each drill (121). All the participants removed their protective gear (helmet, hood, gloves, bunker coat and pants) and recovered in a cool 20°C room after each drill (121). Besides being cooled down using cold towels, firefighters in the interventional group were required to drink 500mls of water, at least 355ml of sports drink and an additional 355 ml of a recovery drink which contained 20g of carbohydrates and 5g of protein within the first 10 minutes of recovery (121). Nevertheless, there was no significant difference reported in the core body temperature and heart rate monitoring post-intervention (121).

In the more recent research by Krishner et al. (2020) (122), fifty male sugarcane workers with normal eGFR in Guatelama, were randomly selected to participate in a three-week study using an electrolyte hydration intervention, which consisted of 2.6 g NaCl, 2 g KCl, 13.5 g carbohydrates (glucose), and 40 kcal, per litre as recommended by WHO (123). Each worker was provided with the standard 2.5 L of electrolyte solution per day (baseline) in Week 1, followed by 5L and 10L per day in Week 2 and Week 3, respectively (122). Even though there were no significant differences in the average electrolyte level and renal function, lesser muscle injury and heat-related symptoms were reported (122).

Besides, a hydration strategy was included in the study by Ioannou et al. (2021), which included agricultural workers in Qatar as well as construction workers in Qatar and Spain (57). Non-hypertensive workers were required to consume 750ml of water which was supplemented with approximately 15g of salt every hour (57). Construction workers in Qatar experienced a significant decrease in core body temperature, but agricultural workers in Qatar experienced a significant increase in heart rates (57). Moreover, there was a significant reduction in the core body temperature and heart rate, as well as an improvement in labour effort among construction workers in Spain (57). All three studies reported a decrease in the prevalence of dehydration post-intervention (57).

Additionally, even though there was no significant difference in the heat-related symptoms, fewer incidences of acute kidney injuries were reported post-intervention among Guatemalan sugarcane workers who took higher electrolyte solutions (104). Future research on this topic is necessary given the scarce and conflicting evidence that supports electrolytes and nutritional supplementation as part of the heat reduction intervention among outdoor workers.

xii- Mechanical fruit cart

As part of the heat reduction approach, a 'mechanical fruit cart, which is a machinery that is able to carry up to 225kg of crops with little effort, was also introduced to the group of agricultural workers in

Table II : Summary of Various Heat Reduction Intervention Studies Among Outdoor Workers

Authors (year)	Sample Occupation	Sample size	Study Design	Type of Intervention	Outcome of study	Effectiveness of intervention used
i. Heat Stress Awareness Program						
McCarthy et al. (2019)	Municipal Outdoor Workers	N = 620	Nonrandomized (Retrospective Analysis)	1. Training – heat-related symptoms, work- rest procedures, water drinking habits 2. Acclimatization 3. Medical surveillance 4. Introduction of first aid protocols	▪ Reduction of HRI ▪ Workers' compensation costs decreased by 50%	▪ sufficient evidence to indicate effectiveness
Butler-Dawson et al. (2019)	Sugarcane workers	N = 517	Randomized	1. Face-to-face communication, posters and pocket urine colour charts 2. Wellness incentives	▪ High incidences of cross-shift AKI even when workers are well hydrated	▪ insufficient evidence to support the effectiveness
ii. Water, Rest and Shade (WRS)						
Bodin et al. (2016)	Agricultural workers	N = 60	Nonrandomized	1. 3 litre water backpack 2. 15 minutes break every hour 3. Portable canopy shade	▪ Fewer heat-related symptoms reported ▪ More regular water intake ▪ Enhanced work satisfaction and productivity	▪ sufficient evidence to indicate effectiveness
Glaser et al. (2020)	Sugarcane workers	Harvest 1, N = 427 Harvest 2, N = 488	Nonrandomized	1. Improved rest schedules 2. Shade tents 3. Improved electrolyte solution	▪ Decrease effect of heat stress on acute kidney injury ▪ Improvement in self-reported water intake	▪ sufficient evidence to indicate effectiveness
Wegman e al. (2020)	Sugarcane workers	N = 80	Nonrandomized	1. 3 litre water backpack 2. 15 minutes break every hour 3. Portable canopy shade	▪ Lesser reduction of eGFR	▪ sufficient evidence to indicate effectiveness
iii. Work/rest ratio						
Ioannou et al. (2021)	Agricultural workers (Cyprus)	N = 6	Randomized	90 seconds of break every half an hour throughout the work day (0600 – 1400)	▪ No significant changes in core body temperature, skin temperature, heart rate and labour effort	▪ insufficient evidence to support the effectiveness
	Agricultural workers (Qatar)	N = 24	Randomized	10 minutes every 50 minutes of continuous work from 0600 to 1100	▪ Increased in heart rate	▪ insufficient evidence to support the effectiveness
	Construction workers (Qatar)	N = 69	Randomized	10 minutes every 50 minutes of continuous work from 0600 to 1100	▪ Significant reduction in skin temperature, heart rate and labour effort	▪ sufficient evidence to indicate effectiveness
	Construction workers (Spain)	N = 10	Randomized	Two breaks of seven minutes (at 12.30 and 16.30)	▪ No significant changes in core body temperature, skin temperature, heart rate and labour effort	▪ insufficient evidence to support the effectiveness
iv. Ice slurry						
Ioannou et al. (2021	Construction workers (Spain)	N = 9	Randomized	Ice slurry (300ml crushed ice) every hour	▪ No significant difference in core body temperature, heart rate and labour effort ▪ Significant increase in skin temperature	▪ insufficient evidence to support the effectiveness

Table II : Summary of Various Heat Reduction Intervention Studies Among Outdoor Workers (continued)

Authors (year)	Sample Occupation	Sample size	Study Design	Type of Intervention	Outcome of study	Effectiveness of intervention used
v. Mixed strategies of work/rest ratio, ice slurries and a combination of both measures						
Ioannou et al. (2021)	Workers in the Tourism industry (Greece)	N = 6	Randomized	1. 90 seconds of planned break every 30 minutes for continuous work 2. ice slurries (3.5ml per kilogram body mass) every hour of continuous work 3. Combination of two minutes of a planned break and ice slurry consumptions (3.4g per kilogram body mass) every hour of continuous work	▪ No significant difference was noted in the core body temperature, skin temperature, heart rate and labour effort in all measures	▪ insufficient evidence to support the effectiveness
vi. Cooling Jackets or Wests						
Chan et al. (2017)	Construction workers	N = 140	No details of randomization	Hybrid cooling vests with PCM and ventilation fan	▪ Lower heat sensation ▪ Reduce RPE ▪ Lower heart rate ▪ Lower perceived strain index ▪ 91% workers prefer wearing the vest during rest time	▪ sufficient evidence to indicate the effectiveness but improvement is still needed to improve comfort
Yi et al. (2017)	Construction workers	N = 10	Nonrandomized	Hybrid cooling vests with PCM and ventilation fans	▪ Reduction in heart rate skin temperature during recovery phase	▪ sufficient evidence to indicate effectiveness
Ashtekar et al. (2019)	Construction workers	N = 29	Nonrandomized	Personal cooling garment (PCG) – A vest with battery-operated motor pump liquid circulating cooling system	▪ Decrease in heart rate and skin temperatures ▪ Workers feel comfortable and have no disruption in their work tasks	▪ sufficient evidence to indicate effectiveness
Hemmatjo et al. (2017)	Firefighters	N = 15	Randomization	Cooling vest with PCM	▪ Reduction in temporal temperature and heart rate with cooling vest ▪ Improve response time and correct cognitive response	▪ sufficient evidence to indicate effectiveness
Chicas et al. (2021)	Agricultural workers	N = 41	Nonrandomized (Qualitative study)	Cooling vest with PCM	▪ Effective in cooling but the vest was heavy and uncomfortable ▪ Long time to switch the cooling inserts	▪ sufficient evidence to indicate the effectiveness but improvement is still needed to improve comfort
vii. Cooling Bandana						
Chicas et al. (2021)	Agricultural workers	N = 41	Nonrandomized (Qualitative study)	Cooling Bandana	▪ Workers felt comfortable and cooling sensation when using the bandana ▪ Usage of bandana was practical, effortless and did not disrupt the work routine	▪ sufficient evidence to indicate effectiveness

Table II : Summary of Various Heat Reduction Intervention Studies Among Outdoor Workers (continued)

Authors (year)	Sample Occupation	Sample size	Study Design	Type of Intervention	Outcome of study	Effectiveness of intervention used
vii. Anti-heat Stress Clothing or Uniform						
Chan et al. (2016)	Construction workers	N = 37	Randomized	Anti-heat stress uniform – Coolmax collar shirt in light blue and Nanotex dry-inside fabric in khaki colour pants, loose fitting, raglan sleeves, front or back seam, and semi-elastic adjustable waist size	▪ Uniform was more comfortable and dryer skin sensation ▪ Enhance work performance by more than 35%	▪ sufficient evidence to indicate effectiveness
Yang & Chan (2017)	Construction workers	N = 16	Randomized	Anti-heat stress uniform – Short sleeved shirt (65% cotton, 35% polyester) and long pants (100% cotton)	▪ Higher level of heat tolerance with decreased perceptual strain ▪ Improved comfort and minimal disruption in work performance	▪ sufficient evidence to indicate effectiveness
Ioannou et al. (2021)	Agricultural workers (Cyprus)	N = 6	Randomized	Ventilated garments - Short-sleeved shirts with integrated electric fan	▪ Reduction of skin temperature ▪ No significant difference for core body temperature, heart rate and labour effort	▪ insufficient evidence to support the effectiveness
	Agricultural workers (Qatar)	N = 12	Randomized	Evaporative garments - Breathable, lightweight work shirt and trousers	▪ No significant difference in skin temperature, core body temperature, heart rate and labour effort	▪ insufficient evidence to support the effectiveness
	Construction workers (Qatar)	N = 32	Randomized	Evaporative garments - Breathable, lightweight work shirt and trousers	▪ No significant difference in skin temperature, core body temperature, heart rate and labour effort	▪ insufficient evidence to support the effectiveness
ix. Anti-heat Stress Uniform + Cooling Vest						
Zhao et al. (2018)	Construction workers	N = 14	Randomized	Anti-heat stress uniform (a polo T-shirt and a pair of trousers) with added Hybrid cooling vests with phase change materials (PCM) and ventilation fans	▪ Lower heart rate ▪ Lower core body temperature ▪ Reduction of PSI	▪ sufficient evidence to indicate effectiveness
x. Cooling Gel Patch						
Hemmatjo et al. (2017)	Firefighters	N = 15	Randomized	Cooling gel containing menthol	▪ No significant differences in physiological strain or perceptual parameters	▪ insufficient evidence to support the effectiveness
Yeargin et al. (2016)	Firefighters	N = 38	Randomized	Head cooling gel pack in helmet	▪ No significant differences in physiological strain or perceptual parameters	▪ insufficient evidence to support the effectiveness

Table II : Summary of Various Heat Reduction Intervention Studies Among Outdoor Workers (continued)

Authors (year)	Sample Occupation	Sample size	Study Design	Type of Intervention	Outcome of study	Effectiveness of intervention used
xi. Forearm Or Lower Body Immersion in Cold Water and Water Dousing						
Colburn et al. (2011)	Firefighters	N = 25	Randomized	Forearms immersion in water (20^{o}C) for 20 minutes	▪ No significant differences in physiological strain or perceptual parameters	▪ insufficient evidence to support the effectiveness
Walker et al., (2014)	Firefighters	N = 74	Randomized	Lower body immersion in cold water (15^{o}C) during 15 minutes recovery session	▪ Lower core body temperature and enhanced cooling rate	▪ sufficient evidence to indicate effectiveness
Yeargin et al., (2016)	Firefighters	N = 38	Randomized	Forearms immersion in cold water (5^{o}c) during 15 minutes recovery period	▪ Improved cooling rate of core body temperature ▪ Lower perceptual strain	▪ sufficient evidence to indicate effectiveness
xii. Nutritional Intervention						
Horn et al. (2011)	Firefighters	N = 23	Randomized	1. Consumption of: i. 500ml of water ii. 355ml of sport drink iii. 355ml of recovery drink 2. Cold towels application	▪ No significant in core body temperature and heart rate	▪ insufficient evidence to support the effectiveness
Butler-Dawson et al. (2019)	Sugarcane workers	N = 517	Randomized	500ml Electrolyte solution packets	Decrease AKI among workers with a higher intake of electrolyte solution	▪ insufficient evidence to support the effectiveness
Krisher et al. (2020)	Sugarcane workers	N = 50	Randomized	Electrolyte solution consisted of 2.6g NaCl, 2g KCl, 13.5g glucose and 40kcal per litre 1. Week 1 – 2.5 L of electrolyte solution per day 2. Week 2 – 5.0 L of electrolyte solution per day 3. Week 3 – 10.0 L of electrolyte solution per day	▪ Same productivity each week ▪ No significant difference in serum and urine osmolality ▪ Lesser heat-related symptoms report over the week ▪ No significant renal impairment ▪ Less muscle injury	▪ insufficient evidence to support the effectiveness
Ioannou et al. (2021)	Agricultural workers (Qatar)	N = 26	Randomized	750ml of water every hour supplemented with ~ 15g of salt	▪ Decreased prevalence of dehydration by 54% ▪ Increased workers' heart rate ▪ No significant difference in skin temperature, core body temperature and labour effort	▪ insufficient evidence to support the effectiveness
	Construction workers (Qatar)	N = 53	Randomized	750ml of water every hour supplemented with ~ 15g of salt	▪ Decreased prevalence of dehydration by 97% ▪ Reduced workers' core body temperature ▪ No significant difference in skin temperature, heart rate and labour effort	▪ insufficient evidence to support the effectiveness
	Construction workers (Spain)	N = 9	Randomized	750ml of cold water every hour supplemented with ~ 15g of salt	▪ Reduced workers' core body temperature and heart rate ▪ Improved labour effort ▪ Decreased prevalence of dehydration by 13%	▪ sufficient evidence to indicate effectiveness

Table II : Summary of Various Heat Reduction Intervention Studies Among Outdoor Workers (continued)

Authors (year)	Sample Occupation	Sample size	Study Design	Type of Intervention	Outcome of study	Effectiveness of intervention used
xiii. Mechanical fruit cart						
Ioannou et al. (2021)	Agricultural workers (Cyprus)	N = 6	Randomized	Machinery which carries up to 225kg of crops with minimal effort)	▪ No significant difference in skin temperature, core body temperature, heart rate and labour effort	▪ insufficient evidence to support the effectiveness
xiv. Heat-related policy						
Su et al. (2020)	Occupational* injury claims	N = 9851	Nonrandomized (Retrospective Analysis)	Administrative Measures of Heatstroke Prevention 1. Reducing working hours and work intensity during hot days 2. Training on HRIs 3. Provision of cooling measures – rest areas, free cold drinks and air conditioning in indoor workplaces 4. High-temperature subsidies	▪ 13% reduction in heat-related workplace injuries ▪ 24% reduction in insurance claims	▪ sufficient evidence to indicate effectiveness

Abbreviations: eGFR – estimated Glomerular Filtration Rate; PCM – Phase Change Material; PSI – Physiological Strain Index; RPE – Rated Perceived Exertion

* Include both indoor and outdoor workers

Cyprus (57). Nevertheless, no significant improvement in the labour effort or decrease in the physiological parameters (57).

xiii- Heat-related policy

The Administrative Measures on Heatstroke Prevention Strategy (AMHP) 2012, which defines employers' responsibilities to provide protective measures to workers, limit outdoor working hours, and offer heat subsidies, has been in effect in China since 2012 (53). 9851 injury claims from March 2011 to February 2013 were included in the retrospective evaluation analysis by Su et al. (2020). The risk of excessive heat-related workplace injuries and insurance claims has decreased significantly by 13% and 24%, respectively after the policy's implementation (53). As more countries are pushing for the establishment of heat-related policies and regulations in response to climate change, evaluation studies are needed to determine this strategy's effectiveness.

The various heat reduction intervention studies among outdoor workers are summarised in Table II.

CONCLUSION

It is often challenging to approve one standard cooling strategy above another for all outdoor occupational groups because of the workers' variety of occupational environments and work activities. Personalised or group-tailored cooling measures which are acceptable, affordable, easily available and sustainable, combined with adequate water-rest cycles, may help enhance the workers' comfort and reduce the disproportionately high incidence of heat-related illnesses and mortality among susceptible outdoor workers. Besides, surveillance for heat stress and monitoring for symptoms and indicators that could lead to heat-related illnesses are essential in occupational health settings. This is to ensure that workers who are observed to be over the heat strain criteria will be withdrawn momentarily and abstained from heat exposure for a period to allow the workers to recuperate and prevent any serious heat-related illnesses such as heat exhaustion and heat stroke. There is still limited evidence on cooling intervention studies that include female workers and other occupational settings. Hence, future cooling intervention studies may need to focus on female workers and other outdoor occupational groups, including municipal workers (sweepers and rubbish collectors) and landscape workers. These groups are also vulnerable to the strenuous workload and exposed to long hours in hot, humid environments. At the same time, there is a need for policymakers to advocate for the implementation and enforcement of heat-related policies and regulations in order to protect the health, safety and well-being of these vulnerable workers particularly as the effects of climate change will lead to more occurrences of extreme heat events.

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