Health and safety risk management in a changing climate: contrasting supervisors and workers perceptions and approaches to heat coping strategies on construction sites

HEALTH AND SAFETY RISK MANAGEMENT IN A CHANGING CLIMATE: CONTRASTING SUPERVISORS AND WORKERS PERCEPTIONS AND APPROACHES TO HEAT COPING STRATEGIES ON CONSTRUCTION SITES

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Global temperature increases and more frequent and severe heat waves pose a substantial heat strain risk to construction workers' health, safety and wellbeing, which could lead to physiological and psychological health conditions. Heat coping guidelines have been defined by occupational regulators; however, they are non-enforceable, not industry specific and informal. Thus, the implementation of heat coping strategies is subject to the employers and workers' awareness and motivation. Studies on heat coping strategies and awareness levels amongst UK construction organisations are limited. This study investigated how construction organisations are adapting to climate change by gathering quantitative data on the heat-related risks perception and adopted heat coping strategies among 50 construction site personnel in five construction sites in the UK. Results showed contrasting understanding of heat-related risks and adopted heat management approaches among supervisors and workers. This exploratory research identified a knowledge gap and highlighted the need to raise awareness of the impact of heat stress on UK construction site personnel to ensure that heat-related health symptoms are identified in time, and heat coping measures are appropriately being implemented.

Keywords: climate change, construction workers, health and safety, heat management, heat stress

INTRODUCTION

Construction site personnel, particularly manual workers, are considered a vulnerable group at risk of heat stress (UK Health Security Agency, 2022). Workers are directly exposed to outdoor temperatures, whilst performing intense physical activity during long working hours, with limited ability to adapt their personal protective equipment (PPE) and difficult access to shade and water. Previous studies (Wuersch *et al.,* 2023; Varghese *et al.,* 2018; Kjellstrom *et al.,* 2016) highlighted the negative impact of heat exposure on construction workers' health and wellbeing, and other unintended consequences such as increased number of accidents, and lower productivity.

Heat-related illness and their symptoms include fatigue, fainting, nausea, heat cramps, dehydration, respiratory distress, cardiovascular disease, heat stroke and even death. These physiological reactions to heat are not uniform, as individuals exhibit different

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responses, depending upon their sensitivity and vulnerability. However, evidence is limited, and more research is required to determine the impacts of heat on diverse groups of workers based on their demographic characteristics, hydration levels, heat tolerance, and acclimatisation (Karthick *et al.,* 2022). In addition, recent research (Crane *et al.,* 2022) investigated the impact of climate change on people's health and reported that exposure to extreme heat and heatwaves had direct and indirect effects on mental health conditions, like anxiety.

The adverse health effects of heat on construction site personnel are preventable through effective and economically viable heat coping strategies. Previous studies suggest that the most effective strategies are mandatory work-rest arrangements and self-pacing, increased fluid intake, optimising or removing clothing, acclimatisation, ensuring regular screening of workers, setting up heat alerts, and supervision and training (Goodman *et al.,* 2023, Morrissey *et al.,* 2021, Edirisinghe and Andamon, 2019). However, previous authors have identified various barriers to the appropriate implementation of these heat-coping strategies. These include a lack of awareness amongst senior personnel (Jia *et al.,* 2019), tension between self-pacing and progress pressure (Jia *et al.,* 2019, Rowlinson *et al.,* 2014), diverse people's heat perceptions, lack of training and peer pressure (Lao *et al.,* 2016).

Occupational regulators such as the Occupational Safety and Health Administration in the United States (OSHA), the Health and Safety Executive in the UK (HSE), or the Australian Institute of Occupational Hygienists (AIOH) have developed heat stress management guidelines and technical manuals. However, they are not enforceable, rather generic and informal, and they are not always feasible to implement in outdoor environments. For example, the HSE encourages UK employers to be responsible and take proactive safety measures (HSE, 2023), but these guidelines do not expand beyond informal best practices (e.g., providing free access to drinking water or using weather-appropriate personal protective equipment) and are not industry specific.

Although construction employers would generally agree that protecting the health and wellbeing of their construction site personnel is the most important reason for combating heat-related illnesses, the development and implementation of heat-related policies is still in its infancy requiring further improvements (Fatima *et al.,* 2023). Furthermore, the literature review suggests that there is little evidence on heat stress prevention in moderately hot weather conditions in occupational settings (Varghese *et al.,* 2018) and more location-specific studies are required to understand heat-related health impacts and practices at the workplaces (Mcinnes *et al.,* 2017).

The United Kingdom (UK), like many other nations worldwide, is experiencing rising temperatures because of global warming. In 2022, the UK suffered the hottest year in records, with temperatures reaching more than 40°C (Kendon *et al.,* 2023). However, there is limited information about the extent to which different heat coping strategies are currently practised in the UK construction industry.

This paper will aim to address this research gap through an exploratory study of the impact of heat stress on construction site personnel, and their preparedness to adapt to the increasing temperatures resulting from climate change. Contrasting perceptions of the problem and actions taken by the different construction site personnel will be explored, to help design effective and tailored measures to manage the impacts of hot temperatures on UK construction sites.

METHOD

A paper-based survey was conducted in July 2023 in five construction sites in London, UK, ranging from a project value of £5M to £125M. A convenience non-probability sampling was used. A total of 50 individuals, all based on a construction site environment, took part in the survey, including project and design managers, site managers and health and safety managers, and manual workers.

A survey was designed to investigate: (i) the impact of heat stress on construction site personnel based on self-reported heat-related health symptoms experienced; (ii) awareness of heat stress illnesses, heat-related H&S risks, and contributing factors; (iii) analytical capacity to assess heat stress risks; and (iv) actions taken to address heat stress on construction site personnel.

A total of 16 closed questions were designed based on previous studies on heat stress (Varghese *et al.,* 2020; Xian *et al.,* 2016), and climate change risks adaptation (Moser and Luers, 2008). Participants were approached by the researcher on a one-to-one basis to request their consent and willingness to participate in the study. Participants completed the paper-based survey in confidentiality. The study was approved by the School of the Built Environment of the University of Reading Research Ethics Committee.

Microsoft Excel was used for data manipulation and analyses. Descriptive analysis (frequencies and percentages) was used to summarise the characteristics of the study population and key variables. Sub-analyses were completed by participants' job role. No reportable differences were identified by age or years of experience.

Fifty construction site personnel completed the survey. Nearly all the participants were male (98%) and white (92%). The most frequent age groups ranged from 25-34 years (N=16, 32%) and 35-54 years (N=24, 48%). Almost half (40%) of the participants had 11-20 years of experience, and 26% had been working in the industry for more than 20 years. The job roles included: office-based (site cabin) professionals, such as project manager, quantity surveyor, design manager (N=16, 32%); site managers and H&S managers (N=19, 38%); and manual workers (N=15, 30%).

FINDINGS

Heat-Related Health Symptoms

Participants were asked to self-report any health symptoms associated with heat exposure while working on a construction site. Nearly half of the respondents (N=21, 42%) confirmed having experienced heat-related health symptoms. The majority of those affected (N=17, 81%) reported experiencing mild symptoms, such as headache or fatigue. Moderate symptoms, such as dizziness or nausea, were reported by 3 participants, and 1 participant reported being severely affected and experienced symptoms such as fainting or seizures.

Minor heat-related health symptoms could be signs of more serious heat-related illnesses. Headache and fatigue are common to heat exhaustion (NIOSH, 2016), which is often considered a precursor to the more serious heat stroke if left untreated. Dizziness and fainting were also reported by the participants. These moderate/major symptoms have been associated with heat syncope (NIOSH, 2016), usually occurring when standing for too long under heat conditions and the body causes the blood vessels to dilate to such an extent that blood flow to the brain is reduced. Other factors that may contribute to heat syncope include dehydration and lack of acclimatisation.

A sub-analysis by participants' job role indicated that more than half (N=12, 57%) of the participants affected by heat exposure were site/H&S managers, followed by manual workers (N=6, 29%) and office-based professionals (N=3, 14%). Results suggest that nearly two thirds (63%) of the site/H&S managers participating in the study had experienced heat-related health symptoms, compared to 40% of the manual workers. This is a surprising finding.

Manual workers are the most vulnerable group, being exposed to heat for longer periods of time, performing intense manual work and having access to less frequent breaks and comfortable welfare facilities than other construction site personnel. The lower figure could be explained by the masculinity culture surrounding the construction industry (Hanna *et al.,* 2020), where these health symptoms are just part of the job, and they are not considered important enough to be reported. On the other hand, only 19% of the professionals working mostly in the site cabins reported having heat-related symptoms. This could be explained by the fact that site cabins can provide more comfortable and adaptive indoor working conditions (e.g., using fans and A/C devices) and easier access to water. Office-based professionals can also adapt their clothing layers, and they undertake less physically demanding work.

Awareness of Heat-Related Illnesses and Health and Safety Risks

Participants were asked to list the heat-related illnesses and health and safety incidents related to heat exposure that they were aware off or had previously witnessed. Results show that participants were able to list 5 different heat-related illnesses, including: dehydration (N=28, 56%); heat exhaustion (N=27, 54%); heat stroke (N=22, 44%); fainting, as a symptom of heat syncope (N=22, 44%); and heat cramps (N=8, 16%).

This question revealed some knowledge gaps. Participants failed to mention heat edema (severe, painful swelling of body parts such as feet, legs, arms and hands) and heat rashes, which are also associated with heat exposure (Xiang *et al.,* 2016). The sub-analyses of the results by job role also identified that heat cramps (painful, involuntary muscle spasms that usually occur during intense exercise in hot environments) were mentioned by 40% of the manual workers, but only by 5% of the site/H&S managers, and 6% of the office-based professionals. Manual workers, being more involved in physical activities than other construction site personnel, are more likely to experience heat cramps.

In addition to heat-related illnesses, a smaller number of participants also mentioned other health and safety incidents associated with heat exposure. These include slips, trips and falls (N=16, 32%); cuts and lacerations (N=8, 16%); equipment failure (N=8, 16%); electrical hazards (N= 7, 14%); vehicle accident due to ground shrinkage (N=1, 4%). Previous similar studies also confirmed an increased number of injuries and accidents due to fatigue, decreased physical performance, and reduced vigilance (Varghese, 2018). However, more information would be necessary to understand the direct or indirect relationship between heat exposure and the incidents reported by the participants.

Awareness of Work and Organisational Factors Contributing to Heat Stress

The survey presented participants with a list of work and organisational factors contributing to heat stress. The most reported work factors include PPE not suitable for hot weather (N=30, 60%); lack of ventilation at the workplace (N=30, 60%);

limited access to water (N=24, 48%); heavy workload (N=21, 42%); and lack of shade (N=21, 42%). Work factors were ranked differently by job role. The unsuitability of the PPE was the most frequently reported work factor among manual workers and site/H&S managers. In contrast, three quarters of the office-based professionals selected the lack of ventilation as the major contributor. This could be explained by more relaxed PPE requirements when working in the site cabins, compared to the full compulsory PPE needs for those walking or working on-site.

A participant commented on the impact of wearing inappropriate PPE on their decision-making when being exposed to hot temperatures, stating " I am concerned about being unable to know if I am making a correct decision due to the temperature in the helmet being 30 degrees". This was also acknowledged by Jia *et al.,* (2016), who found that when the environmental temperature was 32.2 °C, the air temperature inside the workers' helmets was 43.7 °C. Only one third of the manual workers considered limited access to water or shade to be contributing factors to heat stress. Table 1 indicates the number of participants that selected the work factor and the percentage (in brackets) in relation to the group sample.

Table 1: Work factors contributing to heat-related illnesses

Work factors	All (N=50)	Manual worker (N=15)	Site/H&S manager (N=19)	Office-based professional (N=16)
Lack of shade	21 (42)	4 (27)	11 (58)	6 (38)
Heavy workload	21 (42)	5 (33)	9 (47)	7 (44)
PPE not suitable for hot weather	30 (60)	9 (60)	12 (63)	9 (56)
Lack of ventilation	30 (60)	8 (53)	10 (53)	12 (75)
Limited access to water	24 (48)	4 (27)	11 (58)	9 (56)

The number of individuals that selected each organisational factor is presented in Table 2. The most frequently voted organisational factor was the lack of heat stress management policies (N=30, 60%), followed by insufficient breaks or rest periods (N=25, 50%) and inadequate training on heat stress prevention (N=25, 50%). Results also showed different views depending on the job roles. Nearly all the manual workers (93%) agreed that the lack of heat stress management policies was a contributor to heat stress. However, only one third of the site/H&S managers found this factor being relevant.

This could indicate that, although the policies exist and are known by site/H&S managers, they are not communicated appropriately to the manual workers, or they are not clearly implemented. Surprisingly, insufficient breaks were only acknowledged by 27% of the manual workers, being the least agreed contributing factor. However, it is not clear if participants responded based on their personal experience, or if there is a lack of understanding of the benefits of taking breaks to reduce heat stress.

In contrast, insufficient breaks were the most frequently chosen factor by the office-based professionals (63%) and site/H&S managers (58%). Inadequate training on heat stress prevention appeared to be of concern to more than half of the site/H&S managers (58%), and office-based professionals (56%). One participant added "the failure to understand risks is a contributor to heat stress".

Table 2: Organisational factors contributing to heat-related illnesses

Organisational factors	All (N=50)	Manual worker (N=15)	Site/H&S manager (N=19)	Office-based professional (N=16)
Inadequate training on heat stress prevention	25 (50)	5 (33)	11 (58)	9 (56)
Lack of supervision	16 (32)	7 (47)	4 (21)	5 (31)
Lack of heat stress management policies	30 (60)	14 (93)	7 (37)	9 (56)
Insufficient breaks or rest periods	25 (50)	4 (27)	11 (58)	10 (63)

Analytical Capacity to Identify and Monitor Heat Stress Risks

Participants indicated the methods used by their organisation to assess and monitor the heat stress risks and translate them into appropriate preventive measures. Overall, the most common methods focused on conducting regular site inspections (N=28, 56%), and reviewing weather forecasts (N=28, 56%). A smaller number of participants (N=7, 14%) mentioned the use of heat stress monitoring devices. Six participants (12%) reported not being aware of any heat stress risk assessment being undertaken.

More than two thirds (68%) of the site/H&S managers indicated that weather forecast was the most frequently used method. Manual workers and the office-based professionals considered that site inspections were the most common heat stress risk assessment practice (60% and 63% respectively). One third of the office-based professionals indicated that heat stress risk assessment was not completed. This differed from manual workers, who all had the understanding that form of risk assessment was used. Interestingly, more than one third of the manual workers reported using heat stress monitoring devices but none of the site/H&S managers mentioned this approach. This would suggest that the workers would proactively use personalised wearables to monitor their physiological variables.

Actions to Address Heat Stress on Construction Site Personnel

On-site actions undertaken by the participants to address heat stress are detailed in Table 3. The number of individuals that selected each action is presented in the table, together with the percentage (in brackets) in relation to the group sample.

Almost all the participants indicated drinking water (N=45, 90%), and taking frequent breaks (N=35, 70%). This consistent with previous studies (Morris *et al.,* 2021; Xiang *et al.,* 2015). Dehydration is a primary contributor to heat exhaustion, and it can also affect work performance. Whilst participants reported drinking water, further research would be required to assess the amount of water intake. Insufficient water intake of construction workers has been reported in previous studies, mentioning reasons such as: lack of palatable water (Moda and Alshahrani, 2018); to avoid using a toilet due to unhygienic or absence of facilities (Venugopal *et al.,* 2016); and to prevent productivity losses associated with toilet breaks (Morris *et al.,* 2021).

Results also suggested that heat coping strategies vary between job roles, mostly due to the tasks and workplace requirements. For example, office-based professionals indicated using fans and other cooling devices, and shaded rest areas. However, these methods were less frequent among manuals workers, because most of the construction activities take place outdoors the use of fans or cooling devices can be challenging. Similarly, more than half of the office-based professionals mentioned adapting their PPE, whilst only one third of the manual workers and site/H&S managers indicated being able to do so. Although PPE is a health and safety measure to protect workers from construction site hazards, it is perceived as a hazard itself rather than a defence when assessing heat related risks. PPE increases workers' heat strain due to its impermeable materials that block effective heat dissipation (Rowlinson *et al.,* 2014). Limiting exposure time in such clothing, adapting the design and fabric used in PPE to cope with heat, and integrating other individual level cooling strategies would be advisable (Morris *et al.,* 2020).

Taking frequent breaks appeared to be a commonly adopted measure across job roles. Participants were asked about the frequency of the breaks, and more than half of the respondents indicated taking breaks every hour (N=26, 52%), or every two hours (N=9, 18%). However, 30% of the respondents took breaks less frequently than every three hours, or never took breaks. Further research is needed to understand the duration of the break and if any additional heat coping strategy was undertaken during the break (e.g., removing clothing or rehydrating). Previous studies have attempted to define work-to-rest ratios under hot temperatures (Yi and Chan, 2013; NIOSH, 2017). The USA National Institute for Occupational Safety and Health (NIOSH) (2017) establishes workers performing heavy work at 35°C should work for 45 minutes and rest for 15 minutes. This work/rest schedule varies, increasing the break and reducing the work duration as the temperature increases.

Less than half of the participant's indicated work was paused due to hot temperatures. A minority of respondents (N=5) provided further information, indicating that work was stopped when certain temperature value was reached. The reported temperature limit ranged from 28°C to 40°C. Nearly one third of the participants stated that there was no provision of ceasing work in hot temperatures, and another 28% of the respondents were not sure if there were procedures in place. The UK currently has no legal maximum outdoor working temperature. OHS regulatory bodies' advice is that employers need to provide a reasonable environment to ensure employees remain safe and comfortable and act where necessary and where reasonably practicable (HSE, 2023). NIOSH (2017) advises workers to take extreme cautions (and stop work if possible) when performing heavy work from 41°C. It is worth pointing out that these values are defined under the assumption that workers are physically fit, well-rested, fully hydrated, under age 40, and environment has 30% humidity and perceptible air movement, which is not necessarily a true depiction of the construction workers' demographic and physical characteristics.

Table 3: Actions to address heat stress on construction sites

Heat-coping strategies	All (N=50)	Manual worker (N=15)	Site/H&S manager (N=19)	Office-based professional (N=16)
Wearing suitable personal protective equipment	21 (42)	5 (33)	7 (37)	9 (56)
Working during cooler hours	15 (30)	5 (33)	2 (11)	8 (50)
Drinking water	45 (90)	13 (87)	17 (89)	15 (94)
Using fans or other cooling devices	27 (54)	6 (40)	10 (53)	11 (69)
Using shaded rest areas	27 (54)	5 (33)	12 (63)	10 (63)
Taking frequent breaks	30 (60)	10 (67)	10 (53)	10 (63)
Stopping work	22 (44)	6 (40)	8 (42)	8 (50)

CONCLUSIONS

Given the trend of increasing global temperatures due to climate change, this study provides interesting insights regarding the preparedness of UK construction organisations to manage the impact of heat exposure on construction site personnel.

The study investigated the impact of heat stress on construction site personnel and confirmed that nearly half of the participants had experienced heat-related health symptoms, including some associated with serious heat-related illnesses. Contrary to what it was expected, manual workers reported experiencing less symptoms than the site/HSE managers. The paper discussed the inherent masculinity culture of the construction industry, particularly amongst manual workers, and the general perception that construction projects are inherently dangerous.

The paper also researched the preparedness levels of construction site personnel by implementing Moser and Luers (2008) framework: "awareness", "analytical capacity" and "actions". Results suggested that different awareness levels exist between on-site job roles. The paper discussed the lack of experiential awareness as a possible reason. For example, findings showed that office-based professionals, who generally spend more time indoors in a site cabin and thus are less exposed to the heat, could identify less heat-related illnesses than site/HSE managers. Similarly, only a small number of site/HSE managers and office-based professionals, who normally would not perform physically intense activities, could name heat cramps compared to the manual workers. However, the results also suggested that there was a general lack of knowledge amongst the participants on the potential heat-related illness affecting construction site personnel and failed to name some health conditions. The study of the work and organisational factors contributing to heat stress also showed a tendency to focus on the individual's personal experience rather demonstrating an understanding of the impact of heat on others being more exposed. For example, office-based professionals highlighted the lack of ventilation, whilst the unsuitability of the PPE or lack of shade were less of a concern. On the other hand, site/H&S managers and manual workers agreed on the PPE not being appropriate for hot temperatures.

The research also explored the analytical capacity to assess heat stress risks and concluded that there is no standard approach to assess and monitor the risk. Whilst site/H&S managers relied on weather forecasts, office-based professionals and manual workers believed site inspections were the measure generally used. Interestingly, the results suggested that a (small) number of manual workers were using personal wearable devices to monitor the heat stress levels, highlighting the potential of wearable technologies to be more widely used to prevent heat-related illnesses on construction sites.

Finally, the actions taken to manage the impacts of heat stress were also investigated. As previously, the individual's personal circumstances dictated the most common heat coping strategies adopted. Therefore, there is a need to tailor the preventive measures to the different construction site personnel workplace and task demands, to ensure an effective prevention of heat stress.

This study contributes to the understanding of the impact of heat stress on construction site personnel and concludes that there is a need to raise awareness of the impact of heat stress on construction site personnel to ensure that heat-related health symptoms are identified in time, heat coping measures are appropriately being implemented or adopted, and all the individuals working on-site are protected.

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