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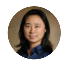
2 authors:

Siyuan Song
Arizona State University



Fan Zhang
University of Southern Mississippi

A Study on Assessing the Awareness of Heat-Related Illnesses in the Construction Industry

Siyuan Song, Ph.D., A.M.ASCE[1]; and Fan Zhang, Ph.D., A.M.ASCE[2]

[1]Dept. of Civil, Construction, and Environmental Engineering, Univ. of Alabama, Tuscaloosa, AL (corresponding author). Email: siyuan.song@ua.edu
[2]School of Construction and Design, Univ. of Southern Mississippi, Hattiesburg, MS. Email: fan.zhang@usm.edu

ABSTRACT

Construction workers often expose to heat stress hazards as temperature and humidity increase. Heat-related illnesses include heat stroke, heat exhaustion, heat cramps, and heat rash conditions. Without immediate and correct treatments, patients may suffer from brain damage or other organ failures, and even death. Heat exposure can also cause fatigue and then lead to other construction accidents. It is crucial to raise awareness of heat-related illnesses and equip people with the means and methods to prevent them from happening. This study aims to assess the current status of people's knowledge of heat-related illnesses using an online survey questionnaire. The results suggest that further heat-related training should put more focus on the training topics of heat-related illnesses prevention strategies, first-aid, and symptom identifications. The participants whose work is directly related to safety have a better understanding of heat-related illness symptoms than the rest. The results also indicate that the participants' knowledge of heat-related illness prevention is related to their age and whether they had participated in heat-related training. The findings of this research can help with the development of future heat-related illnesses training and facilitate construction companies to improve their current safety culture and practices.

INTRODUCTION

Extreme heat is the leading cause of weather-related deaths in the United States (CDC 2021). Environmental heat stress is determined by six key factors, including air temperature, humidity, radiant heat, wind speed, metabolic heat generated by physical activities, and the effect of the clothing worn (Rowlinson et al. 2014). Heat illness stems from heat stress, which occurs when the body cannot lose heat after continuous physical labor, causing increased body temperature and heart rate. Environmental and man-made heat are two types of external heat exposure that occur in the workplace (Xiang et al. 2014). Heat-related illnesses are a group of disorders caused by exposure to heat, including heat cramps, heat rash, heat exhaustion, and heat stroke. Heat-related illnesses may lead to numerous adverse health effects such as physiologic dysfunctions, damage to organs, and death. Heat can also attribute to the increased risk of other injuries on the job site due to sweaty palms, fogged-up safety glasses, and dizziness. Exposure to heat may also reduce brain functions, leading to impaired reasoning ability and thereby creating additional hazards (Park et al. 2017). The majority of heat illness cases reported in the United States occur in the south. However, people in the construction industry should be aware that cases involving heat stress occur everywhere (Tymvios et al. 2016). Therefore, it is crucial to raise the awareness of heat-related illnesses and equip people with the means and methods to prevent them from happening. This study aims to assess the current status of construction practitioners' knowledge of heat-related illnesses by developing and deploying a survey questionnaire.

LITERATURE REVIEW

The number of daily heat-related injuries increases with the increase of the ambient temperature. Seasonal aspects also play a role in the number of heat-related injuries that occur. Dutta et al. (2015) suggest that heat-related illnesses increase in the summer, with 59% of all reports of heat-related illnesses occurring in the summer compared to 41% in the winter months. Heat stress could potentially impede productivity and contribute to job site accidents (Dutta et al. 2015).

Heat-related Illnesses Causations

Heart rate, sweating rate, body core temperature, and skin temperature are recognized as the main indicators for heat strain (Yi et al. 2017). Specific environmental factors causing heat stress are high air temperature, no movement of air, high humidity, and radiant heat. Physical work contributes to the total heat stress of a job because metabolic heat increases in proportion to work intensity (Park et al. 2017). Employees may be distracted and fatigued due to the high temperature (Song et al. 2018). Findings suggest that an increase in incidents may occur during the summer months as the hot weather is more impactful to employees than normal weather (Song et al. 2018). Rising temperatures can adversely affect the per capita income level of a country by reducing the labor productivity level in that country. Furthermore, workers' absenteeism and turnover will increase while productivity will fall during extremely hot weather conditions or sudden changes in temperature (Alshebani et al. 2014). Global warming has led to an increase in the severity and intensity of heatwaves in many countries. The increased frequency of heatwaves due to global climate change has escalated the issue of heat stress. Even if the activity level during a heatwave is low, there is an increased risk of sickness and mortality due to heat stress. There has been an increase in heat waves, particularly in urban areas where construction is most prevalent (Dutta et al. 2015).

Protective clothing and equipment are necessary to reduce injuries in many occupations. However, wearing protective clothing increases heat stress which potentially can cause heat illnesses (Yamazaki 2013). The amount, thermal characteristics, and the type of clothing worn are also important because they alter the rate of heat exchange between the skin and the air (Park et al. 2017). The fundamental aspects of clothing properties and thermoregulation must be understood and appropriately managed in all occupational settings that are frequently exposed to high thermal loads (Lucas et al. 2014). Many construction workers reported that they are dissatisfied with the level of cooling, drinking water, and sanitation facilities available to them. However, they are compelled to tolerate working conditions due to their economic vulnerability (Dutta et al. 2015). Construction workers often work in unorganized sectors and are uninsured (Farshad et al. 2014). Specific subgroups of workers such as migratory workers (due to the lack of acclimatization and poor support network) and women (due to discrimination in the workplace and inadequate sanitation facilities for women) have additional vulnerability factors that put them at increased risk of heat-related illnesses (Dutta et al. 2015).

Heat-Related Illness in The Construction Industry

When analyzing mortalities due to heat-related illnesses during the years 2000 -2010, it is shown that construction workers are the second most at-risk group among all industries, surpassed only by agricultural workers (Rameezdeen and Elmualim 2017). The construction industry accounts for 36.8% of the occupational heat-related mortalities in the United States. Furthermore, over a 10-year time, the risk of heat-related fatality among construction workers in the United States was 13 times greater than workers in other industries (Acharya et al. 2018). Construction workers often perform hard manual work outdoors, which puts them at high risk of injury due to heat stress. The construction industry is very vulnerable to heat stress due to the nature of how construction companies operate and the industry's heavily reliance on manpower (Alshebani et al. 2014). The combination of these increased environmental and metabolic heat loads poses a challenge to the body's cooling mechanisms (Rameezdeen and Elmualim 2017).

The use of heavy machinery and power tools, working on elevated surfaces, heavy workloads, temporary employment by subcontractors on a daily payment basis, and constant, direct exposure to sunlight are all factors that can contribute to the increased risk of heat stress within the construction industry (Xiang et al. 2014). The risk of heat stress is a challenge to both safety and productivity on construction projects because of the physiological effect on declining physical capacity and mental alertness, leading to declining productivity, heat-related illnesses, or accidents on site (Jia et al. 2016). Profit-oriented production and performance targets are common reasons overshadowing or marginalizing heat stress prevention (Xiang et al. 2016). Small companies with ten employees or fewer reported the highest fatality rate due to heat-related illnesses (Rameezdeen and Elmualim 2017). Previous data also suggests that the majority of the incidences took place in contracts undertaken by small contractors (Tymvios et al. 2016).

Prevention Methods

Heat-related illnesses and fatalities can be easily prevented with appropriate rest, shade, and rehydration. The risk of heat stress can be managed in several different ways, including the control of environmental heat stress exposure, management of continuous work time, and enablement of self-paced working (Rowlinson et al. 2014). New workers and all workers returning from an absence of more than a week should begin with 20% of the usual duration of work in the hot environment on the first day, increasing incrementally by no more than 20% each subsequent day. Full acclimatization might take up to 14 days or longer to attain, depending on individual or environmental factors (Arbury et al. 2014). Observation of employees and coworkers is crucial as early detection of heat exertion symptoms is fundamental for preventing progression to worse symptoms (Rameezdeen and Elmualim 2017). The majority of construction workers are aware of and accustomed to the concept of heat stress; therefore, emphasis needs to be placed on cultivating a culture of healthiness at the job site. A few ways in which this goal can be achieved are through enforcing safety regulations, empowering the workers, and motivating employers (Dutta et al. 2015). Researchers found that most construction companies appropriate the highest percentage of discretionary safety funding to safety trainings (Song et al. 2017). Spreading awareness of heat-related illness is considered to be a key to prevention. Suggested measures to prevent heat stress include the installation of ventilation and cooling fans, incorporating equipment that requires less physical labor, providing drinking water to all workers, acclimation of workers to heat through gradual exposure, incorporating loose-fitting clothing, and educating workers on symptoms and treatment of heat stress (Tymvios et al 2016). Heat training is considered to be workers' main source of information about heat stress prevention.

A variety of indices have been developed to measure heat stress, and some of them are designed specifically for the industrial work environment. Wet Bulb Globe Temperature (WBGT) is by far the most widely accepted empirical index for the measurement of occupational heat stress (Chan and Yi 2016). It is recommended that the higher the WBGT and the work intensity is, the longer workers should rest (Takakura et al. 2017). Maintaining hydration is very important for heat stress prevention. Dehydration due to perspiration and metabolic electrolyte imbalances are common in cases related to high temperatures. Many workers report only drinking when thirsty, which reflects the necessity to reinforce the message of rehydration in the workplace. Thirst cannot be relied upon as a guide for the need for water, as 1 % of the total body weight in water is already lost when an individual senses thirst (Chin and Yi 2016). The urine-specific gravity testing is another method that indicates the absolute hydration status of the body. This method is a single measure, non-invasive, easy, and quick test to conduct in the work environment (Farshad et al. 2014).

METHODOLOGY

To better understand people's awareness of heat-related illnesses, an anonymous survey questionnaire was developed and deployed through Qualtrics. The survey study has been reviewed and approved by USM Institutional Review Board under protocol #21-147 before distributed to participants. The authors sent the survey to their primary contacts of multiple construction companies and professional organizations. These primary contacts were also requested to distribute the survey to their employees, coworkers, and members. Therefore, the total number of people who received this survey is unknown and the response rate of this survey cannot be calculated. This survey opened for two weeks and received 43 respondents who entered the survey. The completion rate of the survey is $30/43 \approx 69.8\%$. The following analysis was based on the 30 completed surveys.

Survey Development

To develop the survey questionnaire, multiple sources were referenced, including the papers mentioned in the literature review and information from the OSHA website (OSHA 2021, OSHA Susan Harwood Training Grants 2021). A consent form is on the first page of the survey, and it is a mandatory question. Only consented participants can access the main body of the survey. The survey questionnaire has six parts, as shown in Table 1. The questions under Part I collect the demographic information of participants, including age, gender, education, experience, and job classification. Part II contains 6 questions related to people's awareness of the danger of heat. Part III asks people's knowledge of symptoms of heat-related illnesses. Part IV is about heat-related illnesses prevention and first aid. Four questions in this part are about prevention and one question is about first aid. Part V has four questions related to people's awareness of the employer's responsibility to protect workers. Part VI is related to the participant's training history in the topic of heat-related illnesses. Questions from Part II to Part V are Likert scale type of questions, from the scale of 1 to 10, with 1 being the minimum and 10 being the maximum.

Table 1. Survey questionnaire.

Part I: Demographic information.
Age, Gender, Education, Years of experience in Construction, Job classification

Part II: The danger of heat.
In a scale of 1 to 10 (1 minimal, 10 maximum), how well are you aware of:
- The frequency of accidents, in general, appears to be higher in hot environments than in more moderate temperatures.
- Heat tends to promote accidents that occur because of sweaty palms, dizziness, or the fogging of safety glasses.
- Employees can get burned from accidental contact with hot materials such as steam or metal surfaces.
- When heat stroke does not kill immediately, it can shut down major body organs causing acute heart, liver, kidney, and muscle damage, nervous system problems, and blood disorders.
- Workers suffering from heat exhaustion are at greater risk for accidents since they are less alert and can be confused.
- Mental confusion, tiredness, and irritability may occur when an employee becomes overheated.

Part III: Heat-related illness symptoms.
In a scale of 1 to 10 (1 minimal, 10 maximum), how well do you know the symptoms of:
- heat cramps
- heat rash
- heat exhaustion
- heat stroke

If you know them well, please list some of the symptoms here (optional).

Part IV: Heat-related illness preventions and first aid.
In a scale of 1 to 10 (1 minimal, 10 maximum), how well are you aware of:
- OSHA’s recommendation for heat illness prevention involves three key words: Water, Rest, Shade.
- Workers should be encouraged to drink at least one cup (8 ounces) of water every 20 minutes while working in the heat, not just if they are thirsty.
- The length and frequency of rest breaks should increase as heat stress rises.
- Workers should be given a cool location where they can take their breaks and recover from the heat.
- If you (or a coworker) have symptoms that you believe are related to the heat, in a scale of 1 to 10, how confident are you about what to do next?

Part V: Employer responsibility to protect workers.
In a scale of 1 to 10 (1 minimal, 10 maximum), how well are you aware of the following OSHA recommendations:
- An employer with workers exposed to high temperatures should establish a complete heat illness prevention program, including providing workers with water, rest, and shade.
- An employer should allow new or returning workers to gradually increase workloads and take more frequent breaks as they acclimatize or build a tolerance for working in the heat.
- An employer should plan for emergencies and train workers on prevention.
- An employer should monitor workers for signs of illness.

Part VI: Heat training.
- Have you ever taken any heat-related training before?
- When did you take the heat-related training?
- How often do you take heat-related training?
- Would you like to take heat-related training in the future?

Results and Data Analysis

The demographic information of participants is summarized in Figure 1. Of all the 30 complete responses, 30% of them are over 50 years old, 27% of them are between the age of 41 to 50, 17% of them are between the age of 31 to 40, 23% of them are between the age of 21 to 30, and only 1 person is under age 20. There are 30% of the participants are female and 70% are male. For education background, 53% of them have college degrees, 17% of them have graduate degrees, 13% of them have associate degrees, and 17% of them only finished high school. For the years of experience in construction, 47% of them have over 15 years of experience, 10% of them have 11-15 years of experience, and 43% of them have less than 5 years of experience. Participants have diverse backgrounds in terms of job classifications. These include 4 foremen, 4 project managers, 5 company executives, 3 safety directors, 2 assistant project managers, 2 superintendents, and one in each of the following job classifications: project engineer, business development, clerical, safety professional, safety administration, administrative assistant, field engineer, BIM professional, subcontract admin, and operation manager.

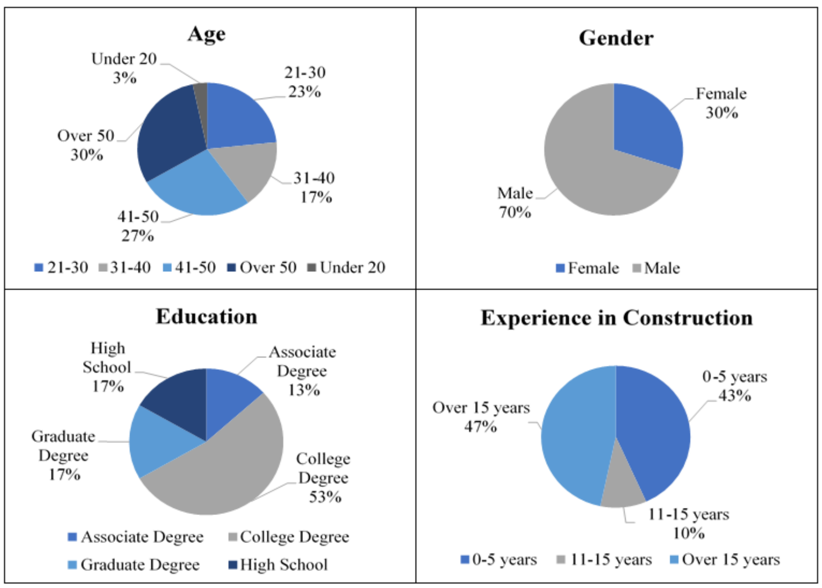


Figure 1. Participants' demographic information summary.

Statistical analysis was applied to the Likert Scale type of questions (Part II-V) includes the danger of heat, heat-related illnesses symptoms, heat-related illnesses prevention and first aid, and employer's responsibility to protect workers (see Table 1). Participant's responses to questions in each group are averaged and used as the score for that group. For example, the group of the danger of heat has 6 questions. A participant's responses to these 6 questions were 9, 8, 10, 9, 10, and 10. The average of these 6 scores is 9.3. Then 9.3 is used as the score for this participant's awareness of the danger of heat. The same calculation methods were applied to each participant's responses. Eventually, each participant has an average score for their awareness level for the danger of heat, heat-related illnesses symptoms, heat-related illnesses prevention, heat-related illnesses first aid, and employer's responsibility to protect workers. This data was imported to the statistical analysis software R to do the analysis. Figure 2 shows boxplots of the five groups with means and spreads of the data. The results indicate that participants have a better knowledge of the danger of heat (mean = 8.02) and the first aid for heat illness (mean = 7.66). Their knowledge of heat-related illness symptoms is relatively lacking (mean = 6.83). The responses for first aid have a wider spread (standard deviation = 1.86) than the others, followed by heat-related illnesses symptoms (standard deviation = 1.75). The mean for people's understanding of the danger of heat is higher than the mean for symptoms and its spread is much smaller than the others, which indicates that people have a good understanding of the danger of heart and the differences among participant's knowledge is small.

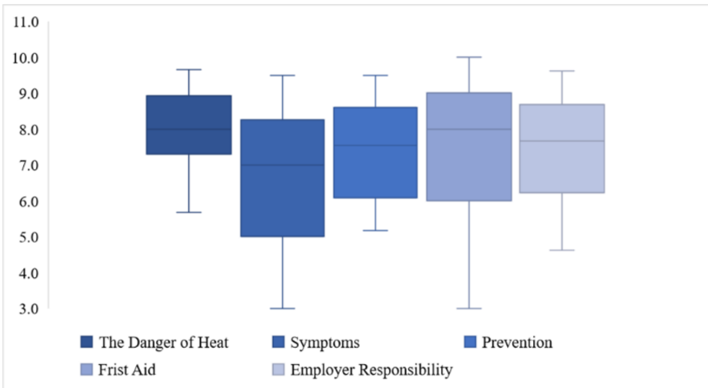


Figure 2. Boxplots of the five groups.

To explore the impact factors of people's knowledge of heat-related illnesses regarding their age, gender, education, experience, job classification, and training history, five linear regression models were applied. For example, the first model used the participants' scores for the group of the danger of heat as the dependent variable and the categorical variables of age, gender, education, experience, job classification, and training history as the independent variables. The respondents' job classifications are very diverse, so they are put into two main categories, people's job functions are directly related to safety and not directly related to safety. The p-values of independent variables are listed in Table 2. The second model use heat-related illnesses symptoms as the dependent variable and the same set of independent variables as the first model. All five models use the same independent variables and the dependent variables for each model are different.

Table 2. P-values for the five linear regression models.

	The danger of heat	Symptom	Prevention	First Aid	Employer responsibility
Age	0.96	0.60	0.06	0.76	0.38
Gender	0.81	0.50	0.84	0.30	0.95
Education	0.50	0.85	0.62	0.51	0.25
Experience	0.78	0.62	0.85	0.99	0.95
Job Title	0.46	0.06	0.36	0.34	0.74
Training	0.18	0.51	0.47	0.17	0.47
R-square	0.28	0.43	0.50	0.40	0.40

According to the results in Table 2, there is suggestive but inconclusive evidence (p-value = 0.06, R-square = 0.43) that participants' knowledge of heat-related illness symptoms is related to their job classifications. People whose job functions are directly related to safety (safety director, safety professional, and safety administrator) have a better understanding of heat-related illness symptoms than those whose job functions are not directly related to safety. There is also suggestive but inconclusive evidence (p-value = 0.06, R-square = 0.50) that people's knowledge about heat-related illnesses' prevention is related to their age. The group with the most heat-related illnesses' prevention are participants from 21 to 30 years of age. According to the data, all of the participants who are between 21 and 30 years of age have taken heat-related illnesses training. No other factors are significate enough to make a difference in responses (p-value > 0.1).

CONCLUSION

This study is an attempt to get a better understanding of people's awareness of heat-related illnesses in the construction industry. The questionnaire was sent out to construction practitioners through email, which contains an anonymous link to the survey. The survey was open for three months and a total of 43 responses were received, including 30 complete responses. The survey includes participants' demographic information and questions to evaluate their awareness of the danger of heat, knowledge of symptoms of heat-related illnesses, heat-related illnesses prevention and first aid, awareness of employer's responsibility to protect workers, and participants' training history in the topic of heat-related illnesses. The results show that participants' knowledge of heat-related illness symptoms is lacking, and it is related to participants' job classifications. Those whose work is directly related to safety have a better understanding of heat-related illness symptoms than those whose work is not directly related to safety. It is suggestive that participants' knowledge of heat-related illness prevention is related to their age and the age group between 21 to 30 has the most knowledge which can be attributed to the fact that all participants who are between 21 to 30 years of age have taken previous training in heat-related topics. The findings of this study suggest construction companies elaborate on the topics of symptoms, prevention, and first aids of heat-related illnesses in their safety and health trainings. The results of this study represent only this group of participants, and it cannot be inferred to a larger population. Most of the respondents are working in Mississippi and Alabama. Future research will be applied to a wider group of construction people from other parts of the country.

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