HEAT ILLNESS
A Descriptive Analysis Within the U.S. Construction Industry

By Nicholas Tymvios, Michael Behm and Yunyan Andrea Jia

IN CONSTRUCTION, a large portion of the work is performed outdoors. Extreme temperatures influence worker safety, and during summer months workers experience heat stress. The aim of this article is to increase awareness of the underreported hazard of heat stress in the U.S. through an epidemiological analysis of the heat-related fatalities and hospitalization cases recorded in the OSHA incident report database. This article adds to the body of knowledge by identifying heat stress as an overlooked occupational health hazard in the U.S. construction industry, and it aims to add value to industry practitioners and policymakers seeking to positively impact overall safety and health in construction.

Heat stress is the overall heat load on the human body that includes temperature, humidity and radiant heat in the thermal environment, and metabolic heat generated by physical activities (Lopez, 1996). Heat illness is the result of the body's inability to expel heat, causing excessive sweat loss or an overly high body core temperature. Ailments that arise on construction sites because of excess heat are heat stroke, heat exhaustion, heat syncope (fainting) and heat rash (Lopez, 1996; McKinnon & Utley, 2005).

As reported by McKinnon and Utley (2005), using information provided by Bureau of Labor Statistics, 40% of heat-related deaths in 2002 occurred in construction. No comprehensive studies have investigated heat stress in the U.S. construction industry, while the majority of the inves-

KEY TAKEAWAYS

- Heat-related illness in the U.S. construction industry is an underreported and under-researched OSH hazard, and these workers are potentially exposed to extreme temperatures that can adversely affect their well-being.
- This study used OSHA data to locate heat-related events. Most heat-related cases were found in California, although this is due to that state's emphasis program on heat and indicates underreporting or under-identification of work-related heat illnesses in other states.
- Without a specific heat-related standard, OSHA uses the General Duty Clause to cite employers, but only after an incident occurs.
- This article aims to increase awareness of the hazard of heat stress, which seems to be underreported, and to encourage policymakers to improve reporting requirements in all U.S. states.

KONSTANTIN AKSENOV/ISTOCK/GETTY IMAGES PLUS tigations occurred in other countries, such as Australia (Jia, Loosemore, Gilbert, et al., 2016), Hong Kong (Chan, Wong, Wong, et al., 2012; Rowlinson & Jia, 2015), the Middle East (McDonald, Shanks, & Fragu, 2008) and China (Li, Chow, Zhu, et al., 2016). Research in the U.S. has produced industry guidelines from NIOSH (Jacklitsch, Williams, Musolin, et al., 2016) and American Conference of Governmental and Industrial Hygienists (ACGIH, 2015), and informational materials published by OSHA (2014). California is an example of a state that has taken the lead in standard development. That state's heat illness prevention standard for outdoor workplaces took effect in 2006 and was amended in 2015. It includes provisions for access to water, access to shade, emergency response, acclimatization, training and a written heat illness prevention plan (State of California DIR, 2015).

Methodology

Data Sources

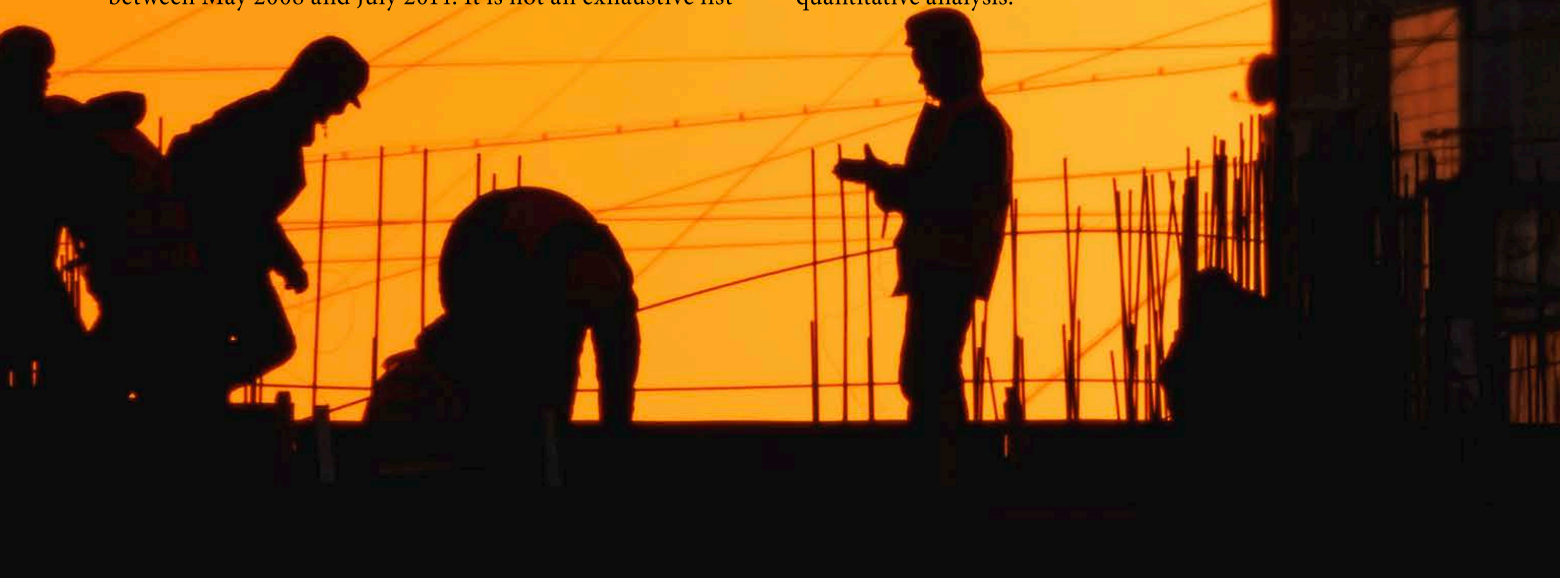
To investigate the current trends in heat-related incidents, the authors used OSHA's (2019a) Integrated Management Information System (IMIS) to collect data on heat stress fatalities and hospitalizations in the construction sector. The data search was accomplished using the following keywords: *heat exhaustion, heat stroke* and *heat*, and the construction sector standard industrial classification (SIC) codes for major groups 15 (building construction general contractors and operative builders), 16 (heavy construction other than building construction contractors), and 17 (construction special trade contractors). The search was performed Aug. 9, 2015, and the case studies for inclusion in the analysis was limited to the last 5 complete years of available information at the time. Therefore, the data included were limited to a 5-year period from Jan. 1, 2009, through Dec. 31, 2013. From the search, 65 unique cases were identified. Nine of the 65 cases were eliminated after reviewing the inspection summaries due to not being related to heat stress or OSHA determining the case to be not work related. The final 56 valid cases were used for the results and analysis presented in this article. A similar investigation using OSHA's IMIS to collect incident data has been conducted in the past, examples of which include an investigation on lead exposure incidents (Henn, Sussell, Li, et al., 2011) and noise exposures (Middendorf, 2004).

Another resource for potential data is the OSHA heat fatalities map (OSHA, 2019b). This map and the text summaries show locations of outdoor worker, heat-related fatalities between May 2008 and July 2014. It is not an exhaustive list of all worker fatalities from heat exposure during this period but shows those reported to OSHA. There are 110 cases on the OSHA heat-related fatality map with 48 being in the construction industry. All the construction-related fatalities in the same 5-year period from Jan. 1, 2009, through Dec. 31, 2013, were cross-referenced with the search from the OSHA IMIS search, and three additional cases were found. These cases did not list the keywords (*heat exhaustion, heat stroke* and *heat*) from the original search but the incident summary text verified that they met the criteria for heat-related incidents in the construction sector. Sixteen other cases from the heat fatality map were unique cases but they did not have an incident report, which limited the details that could be extracted. All 75 (56+3+16) were used in the descriptive analysis, but most statistical analysis was limited to the 59 complete cases (78.7%). This analysis is not inclusive of all heat-related illnesses in the construction sector in this time frame, but it is complete in terms of the electronic information available through OSHA's website.

From each case study the data collected included event date; SIC code; month of incident; time of incident; days until OSHA inspection; state of incident; project end use; project type; project cost; initial OSHA penalty; current OSHA penalty; acclimatization issues mentioned; and the standard cited by OSHA. The information necessary to assess climate conditions and humidity values is not readily available from the reports. Specifically, temperature was recorded for 22 of the identified cases (29%), while humidity was recorded for only four (5%).

Data Analysis

Independent t-tests were used to explore the differences in numerical categories (OSHA penalty cost and time to inspection). The other data were categorical in nature and relationships were explored and analyzed with a chi-square test of independence. Statistical significance was noted at the 0.05 level. The statistical software SPSS v22 was utilized for all statistical analyses. The qualitative data of the cases (i.e., descriptive scenario of the accidents) are summarized to further interpret and explain the findings of quantitative analysis.



CALIFORNIA HEAT ILLNESS PREVENTION STANDARD

Following is a summary of the California Code of Regulations, Title 8, Section 3395, Heat Illness Prevention.

Provision of Water

Employees shall have access to potable drinking water, which must be fresh, pure, suitably cool, free of charge and close to where the employees are working. If plumbed water is not available, sufficient water quantity should be provided at the beginning of each shift.

Access to Shade

•In temperatures higher than 80 °F, shade must be present and as close as practicable to work areas, either open to the air or be provided with ventilation or cooling. The amount of shade must be enough to accommodate employees on recovery or rest periods, and be as close as possible to employees.

•Employees should be allowed and encouraged to take preventive cool-down rest in the shade as needed to protect themselves from overheating. Such employees shall be monitored and asked about heat illness, encouraged to remain in the shade, not be ordered to get back to work until any symptoms or signs of heat illness are abated.

•If a worker is seen to be experiencing symptoms of heat illness during cool down, the employer shall provide appropriate first aid and emergency response.

High Heat Procedures

In temperatures exceeding 95 °F the following should be implemented:

•ensuring that effective communication is maintained so that employees can contact their supervisor if necessary;

•observing employees for alertness and symptoms of heat illness by one or more of the following:

a) supervisor designated for 20 or fewer workers;

b) mandatory buddy system;

c) radio communication of sole employee by radio or cell phone;

d) other effective means of communication.

•designating one or more employees on each site as authorized to call emergency services;

•reminding workers to drink water throughout their shifts;

•reviewing high heat procedures during preshift meetings;

•ensuring that employees take a minimum 10-minute net preventive cool-down rest period every 2 hours.

Emergency Response Procedures

An employer shall implement effective emergency response procedures that includes effective communication to contact emergency medical services, adequate response with first aid, how medical services are provided, transporting employees to emergency medical providers if necessary, and ensuring that access and directions are provided to emergency personnel.

Acclimatization

Employees shall be observed by a supervisor during heat waves, and newly assigned employees at high heat areas shall be closely observed for the first 14 days of employment.

Training

Effective training for employees and supervisors anticipated to be exposed to risk of heat illness should take place on the following topics: environmental and personal risk factors to heat illness; employer's responsibilities and procedures regarding heat illness; importance of frequent water consumption; importance and methods of acclimatization; types of heat illness; importance of immediate reporting; and responding to signs of heat illness.

Heat Illness Prevention Plan

An employer shall establish, implement and maintain an effective heat illness prevention plan that is in writing, in English and a language understood by the majority of the workers, and made available to the work site. The plan must include, at a minimum, procedures for the provision of water and shade, for response during high heat, for emergency response and for acclimatization.

Results

Of the 75 heat-related cases that were found and analyzed using the methods described, 48 were fatalities and 27 were hospitalizations. Most instances (79%) occurred in June (23), July (23) and August (13). Thirty-three (44%) cases occurred in California. With California's regulations and emphasis on heat-related illnesses, more reporting of these heat stress cases may occur in California compared to other states. Texas recorded the second highest number of cases (8) in the authors' data set with the rest of the cases coming from various states across the U.S. Fifteen (20%) of the cases occurred on unionized construction sites.

OSHA Citations & Violations

The average time for an OSHA inspection was 15 days after the incident for fatalities and 8.2 days for hospitalizations; the difference was not significant ($p = 0.20$). California had a quicker response time to conduct the inspection visit (6.8 days) compared to other states (17.1 days), although the result was again not significant ($p = 0.08$). The time lapse to conduct an investigation can be a factor for accurately recalling and understanding primary causes of incidents leading to results with a lack of precision (Johnson, 2002). Okstad, Jersin and Tinmannsvik (2012) warn that if a considerable time gap exists between the incident and the inquiries, the potential exists for misleading information or lack of information.

The employer was initially issued a monetary citation in 50 (67%) of the cases. The average initial penalty per case was $11,309. Many OSHA citations are contested, and heat-related illness is no exception. Thirty-eight of the 50 initial cases with violations were reduced and three were fully reduced to zero dollars. The average final penalty per case was $6,758. The average initial penalty for hospitalizations ($16,044) was much greater compared to fatalities ($8,646) and the difference was highly significant ($p = 0.003$). It is particularly interesting that fatalities would be penalized less than hospitalizations. The average initial penalty for inspections in California ($15,495) was much greater compared to all other states ($7,761), and the difference was highly significant ($p = 0.003$). There was no relationship between case type (fatality/hospitalization) and whether OSHA issued a citation ($p = 0.88$).

Because there are no specific OSHA standards related to heat exposure and heat-related illnesses, OSHA uses various standards to cite noncompliance. The most frequently cited OSHA violation ($N = 14$) was that the employer did not notify OSHA offices when a reportable heat-related illness occurred. With regard to heat-related illness, 29 CFR 1904.39(a)(1) and (a)(2) require OSHA to be notified within 8 hours after the death and within 24 hours after the in-patient hospitalization of one or more employees of any employee as a result of a work-related incident. The second most frequently cited standard ($N = 12$) was 1926.21(b)(2), which states that "the employer shall instruct each employee in the recognition and avoidance of unsafe conditions and the regulations applicable to his work environment to control or eliminate any hazards or other exposure to illness or injury." OSHA's General Duty Clause, Section 5 (a)(1), was cited eight times. The General Duty Clause states that "each employer shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employee."

Acclimatization

Acclimatization is the physiological adaptation of the human body to heat (ACGIH, 2009; Rowlinson, Jia, Li, et al., 2014). Eleven of the cases mentioned acclimatization as an issue. This was a dichotomous variable, with "yes" when acclimation was mentioned and "no" when acclimatization was not mentioned. Of those cases, seven of the incidents occurred on the employee's first day of work; two occurred on the second day and two on the fourth day. No statistically significant relationship exists between acclimatization and the incident being a fatality or hospitalization ($p = 0.19$). In their review of heat-related illness cases in 2006 for all industry sectors, California (Prudhomme & Neidhardt, 2007) identified 82% of the cases occurred during a period of potentially incomplete acclimatization. This difference in the California results might be explained by the effect of the new heat stress regulations instructing safety inspectors and other safety professionals to ask and look for acclimatization issues.

Time of Day

In the OSHA data, 29 of the cases include a record of the time of the incident occurrence. Table 1 shows the number of cases by time of day reported based on the hour. Two peaks of incidents can be observed at the time of before lunch and in the afternoon between 2:00 p.m. and 4:59 p.m. The result is highly consistent with the findings of a Hong Kong study (Jia, Rowlinson & Ciccarelli, 2016).

Type of Projects (Renovation/New Construction)

Thirty-one of the cases occurred during new construction whereas 25 occurred during alteration of refurbishment. Five were classified as "other" and 16 were missing in the data. When the authors analyzed the relationship between the two most common project types, fatalities were related to new construction compared to alterations and refurbishments ($p = 0.02$).

Types of Projects Classified by End Use

OSHA classifies the end use for construction-related inspections. Table 2 shows the distribution of cases by end use. Forty-eight of the projects listed an end use while 27 were missing. There was no relationship between fatality and end use category.

Project Cost

OSHA classifies the project cost in cost categories for construction-related inspections. More than half of the heat-related incidents were on smaller projects (less than $50,000). For relationship tests, the project cost categories were collapsed into less than and more than $50,000, but no relationships were discovered. The descriptive data indicates that smaller projects may not manage heat-related issues effectively compared to larger projects.

History of Heat Illness

Those who had heat illness in the past are likely to experience another case. This may also be because of particular personal body system conditions, but it can be also related to training or job pressure particularly for newcomers seeking acceptance from coworkers. This was the scenario in one of the investigated cases, in which a worker was hospitalized for heat stress on his first day of work due to dehydration, and was prescribed a 3-day sick leave. However, he died of heat stroke on his first day back.

TABLE 1
HEAT STRESS INCIDENTS BY TIME OF DAY

Time of day	Incidents
Before 11:00 a.m.	2
11:00 a.m. to 12:00 p.m.	4
12:00 p.m. to 1:00 p.m.	2
1:00 p.m. to 2:00 p.m.	3
2:00 p.m. to 3:00 p.m.	6
3:00 p.m. to 4:00 p.m.	5
4:00 p.m. to 5:00 p.m.	5
After 5:00 p.m.	2
Total	29

Note. Data from "Fatality and Catastrophe Investigation Summaries," by OSHA, 2019, retrieved from www.osha.gov/pls/imis/accidentsearch.html; and "Heat Fatalities [Map]," by OSHA, 2019, retrieved from www.osha.gov/SLTC/heatillness/map.html.

TABLE 2
HEAT ILLNESS INCIDENTS BY CONSTRUCTION SECTOR

Construction sector	*N*	%
Commercial building	16	33
Residential building	15	31
Highway	7	15
Other construction projects	10	21
Total	48	100

TABLE 3
HEAT ILLNESS INCIDENTS BY CONTRACT SIZE

Project cost	*N*	%
Less than $50,000	31	53
$50,000 to $250,000	5	8
$250,000 to $500,000	5	8
$500,000 to $1 million	6	10
$1 million to $5 million	8	14
$5 million to $20 million	3	5
$20 million and more	1	2
Total	59	100

Note. Data from "Fatality and Catastrophe Investigation Summaries," by OSHA, 2019, retrieved from www.osha.gov/pls/imis/accidentsearch.html; and "Heat Fatalities [Map]," by OSHA, 2019, retrieved from www.osha.gov/SLTC/heatillness/map.html.

Discussion

The authors' analysis of the OSHA heat illness incident records reveals a pattern consistent with previous research conducted in Hong Kong (Rowlinson & Jia, 2014; 2015) and anecdotal evidence in Australia that the high-risk time of the occurrence of heat illness is approximately 11:00 a.m. and from 2:00 p.m. to 4:00 p.m. during the day. Compared with the U.S., Australia and Hong Kong have a long history of research about heat stress, and existing guidelines are comprehensive and well informed (Chan, et al., 2012; Jia, Loosemore, Gilbert, et al., 2016; Rowlinson & Jia, 2014; 2015). No specific guidelines or regulations exist that help construction companies identify and mitigate the specific problems that lead to heat illness on construction sites.

In contrast, industry-specific guidelines were developed in many other industries in the U.S. for effective management of the local risks such as agriculture (EPA, 1993) and the U.S. Air Force (U.S. Department of the Army and Air Force, 2003). Further development of specific guidelines for vulnerable occupations has been noted as a pressing need for international standards as a whole (Parsons, 2013). So far, the Hong Kong construction industry has updated its industry-specific guidelines with detailed specifications of managing the upper stream stakeholders to control the risk (CIC, 2013), evidence of the guidelines has been reported in Rowlinson and Jia (2014; 2015); Rowlinson, Jia, Li, et al. (2014); and Jia, Rowlinson and Ciccarelli (2016).

While Hong Kong is struggling to put some of the issues to legislation, the construction-specific guidelines offer useful information about defining responsibilities and actions for the multiple stakeholders involved in construction projects. In Australia, the Construction, Forestry, Mining and Energy Union (CFMEU, 2016) has heat stress guidelines in several states such as New South Wales; however, the guidelines lack empirical evidence. In the case that the union tries to ensure workers' financial interest, the heat stress guidelines are often ignored (Jia, Loosemore, Gilbert, et al., 2016).

Conclusion

Underreporting of occupational injuries and illnesses is a major drawback within all industrial settings (Leigh, Marcin & Miller, 2004; Rosenmann, 2016). The U.S. House of Representatives (Miller, 2008) reports that up to 69% of all occupational injuries and illnesses never make it into existing reporting systems. [For a detailed discussion of issues in the construction sector, see Behm, Lingard & Bruening (2014), and Lipscomb, Nolan, Patterson, et al. (2013)]. In response to this phenomenon, National Academies of Sciences, Engineering and Medicine (2017) launched a study, Developing a Smarter National Surveillance System for Occupational Safety and Health in the 21st Century.

It is evident by observing the recorded heat illness cases that there is underreporting of such cases in the U.S. In California, 34 cases were recorded during the period of investigation while the rest of the country recorded only 44 cases. It is surprising that other states (e.g., Florida, Georgia, Alabama, Mississippi, Louisiana) where heat and humidity would likely factor into substantially more reports of heat stress are reporting so few. This suggests that California implements a more robust reporting system and that other states should follow suit with similar measures especially for surveillance and reporting (State of California DIR, 2015). That said, heat-related illnesses not resulting in a fatality or hospitalization overall might be underreported because of the varied symptoms that make it difficult for such illnesses to be formally identified as an incident.

Recent literature has identified that underreporting of heat-related incidents is a problem in the U.S. Specifically, Sugg, Konrad and Fuhrmann (2016) suggest that heat triggers underlying health conditions that lead to hospitalizations, and heat exposure is not the primary diagnosis. This underreporting was also recognized in a NIOSH report, which states that since heat-related illnesses are not recognized by workers and employers, they are not reported as heat-related illnesses, while only the days away from work are reported (Jacklitsch, Williams, Musolin, et al., 2016). The report also states that the actual number of occupational heat-related deaths is unknown, and the number of workers exposed to heat is not available. An additional factor that causes an underreporting of heat-related deaths occurs when these deaths happen during a heat wave. The NIOSH report states further that because of the concurrence of heat waves, heat-related occupational illnesses are often "misclassified, unrecognized, or not reported at all" (Jacklitsch, Williams, Musolin, et al., 2016).

The underreporting of work-related heat stress cases is a limitation of the authors' research method that must be acknowledged. NIOSH should consider adding enhanced heat exposure surveillance research into its construction sector portfolio. As observed in the data collected in this investigation, temperature and humidity information was lacking. The authors also suggest that any future research should include a more detailed documentation of weather-related factors of heat stress, and officials collecting information during incident investigations should aim to collect this data as completely as possible.

Contractors must be educated to understand the signs of heat stress and heat illness, and to provide the necessary protection measures to their workers. Contractors should be educated on the importance of acclimatization, breaks during work, and avoiding scheduling work during the warmest parts of the day. Enforcement agencies such as federal and state OSHA should increase inspections during the summer months to ensure that the necessary heat stress prevention measures are taken. Judging from the contract amounts (Table 3, p. 43), the majority of incidents (53%) took place in contracts that had a value less than $50,000, which suggests that smaller contractors experience the majority of the heat-related incidents. OSHA and other local agencies must educate contractors and workers alike and emphasize the education of smaller contractors as well as specific resource support. Such education initiatives should stress the importance of protection and prevention measures, as well as cost-effective measures that contractors can implement. In addition, the authors propose the inclusion of a module on heat stress for OSHA 10 and 30 certifications to increase awareness of the symptoms and causes of heat-related illnesses in construction.

With that in mind, it is necessary to identify the specific prevention and protection measures being practiced on construction sites, and how effective they are. The authors suggest that a more in-depth research study be conducted to catalog and match these measures with different temporal, situational and work characteristics to provide practical guidelines to contractors. A further analysis could use a cost-benefit model as well. Research should also be conducted into monitoring measures that can trigger a warning when an employee is experiencing signs and symptoms of a heat-related incident. Such monitoring could be self-monitoring by the employee, monitoring by the supervisor or crew leader, or through the use of technology. PSJ

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Data Availability

Data generated or analyzed during the study are available from the corresponding author by request. Nicholas Tymvios may be reached at nt013@bucknell.edu.

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