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Heatwaves, Traumatic Injuries, and Barriers to Heat Safety Program Implementation

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Abstract

As global temperatures continue to rise, environmental heat exposure has emerged as a safety concern for outdoor workers. While much focus has been placed on the agricultural industry, construction workers are also at risk. The goal of this project was to understand the association between temperature and risk of traumatic occupational injury among construction workers in Colorado. We also aimed to assess the current beliefs and practices around heat safety at construction sites in the state. Taking a mixed methods approach, we leveraged data from Pinnacol Assurance, a workers' compensation insurer in Colorado, and publicly accessible meteorological data to retrospectively assess the association between temperature and the risk of and cost of injury. We recruited four construction businesses in the state and conducted a needs assessment and interviews with owners/safety managers and workers to assess attitudes and practices around workplace heat safety. The findings of this study support previous research suggesting that heat acts as a hazard multiplier for injury. Importantly, this study identified key barriers to heat safety implementation in the workplace, including lack of knowledge and resources to address the danger.

Key Findings

- In the state of Colorado, increased weekly average temperatures were associated with increased risk of traumatic injury among construction workers.
- No association was observed between increasing temperatures and increasing cost of workers' compensation claims among Colorado construction workers.
- Acclimatization programs have been difficult for workplaces to implement.
- There were mixed thoughts on whether heat was a safety concern and the effectiveness of heat safety training.
- There is a need to develop safety culture around heat safety, especially as it pertains to taking rest breaks for recovery.

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Introduction

Exposure to heat extremes has implications for human health worldwide. Workers are one of the most vulnerable populations for experiencing negative health impacts of heat extremes. Excessive heat exposure is a particular problem for workers because of their internal heat production when working strenuously.[1] This is especially true for workers in construction who work outside for long hours.

Construction workers accounted for 36% of heat-related deaths in the United States from 1992 to 2016, despite comprising only 6% of the total workforce.[2] From 2011 to 2019, the rate of occupational heat-related injuries and illness among construction workers was nearly 80 per 1,000,000 worker-years, compared to 20 per 1,000,000 worker-years among the general worker population.[3] In 2017 and 2018 there were 47 fatalities of construction workers due to exposure to environmental heat reported to the Bureau of Labor Statistics.[4]

Beyond heat-related death and illness, recent research has shown a relationship between increasing outdoor temperatures and non-fatal traumatic injuries. Among construction workers in Washington state, researchers observed a 0.5% rise in the odds of an injury with each 1°C increase in humidex, a measure of heat and humidity.[5] Even with the number of injuries attributable to heat being underreported given the complexity of elucidating heat as the cause of the injury,[6] it has been shown that higher outdoor temperatures increase the risk of occupational injury, regardless of the setting.[7]

Despite the undue burden of heat-related death, illness, and injury faced by construction workers, there is currently no federal standard beyond the General Duty Clause that protects them from outdoor heat exposure. Currently, the Occupational Safety and Health Administration (OSHA) has a proposed rule to address this gap.[8] However, while effective interventions to mitigate the effects of heat on physical performance have been developed,[9] they are often not efficacious when applied to the work-setting.[10] This gap in translation from the lab to the "real world" is likely due to a lack of taking a participatory-based approach to the intervention design, resulting in a lack of practicality of the intervention strategies in the construction industry.[11] This results in interventions that do not meet the needs of the targeted workforce. A previously funded CPWR Small Project titled "Aluminet: An Intervention for Heat-related Illness among Construction Workers," which aimed to assess the efficaciousness of cooling technologies in the workplace, is one of the few identified workplace interventions, but it found no evidence of effect within the studied workforce.[10] That study team noted that employers and worker participants had concerns about the intervention, which likely resulted in it not fully being adopted.[10] This highlights a common issue of not soliciting from employers and workers the barriers they face.[12]

Objectives

The primary goal of this study was to identify the barriers and facilitators of heat safety programming at construction businesses in Colorado to inform future recommendations and implementation of workplace interventions. This project had two primary objectives to meet this goal. The first was to assess the association between temperature and risk of traumatic injuries among the state's construction workers. The second was to identify and describe the current beliefs and practices around heat safety at Colorado's construction businesses.

Methods

To accomplish our primary objectives, we used a mixed-methods approach. Quantitative data analysis was used to understand the relationship between temperature and risk of traumatic occupational injuries. Qualitative data analysis was used to identify current beliefs and practices around heat safety. This study was approved by the Colorado Multiple Institutional Review Board (COMIRB # 23-2560).

Quantitative Data

Occupational Injury Data

Data to understand the association between temperature and risk of traumatic occupational injuries was derived from two sources. Traumatic injury data was provided by Pinnacol Assurance, a workers' compensation insurer in Colorado. Traumatic injuries were considered those with an injury nature of amputation, concussion, contusion, crushing, dislocation, foreign body, fracture, laceration, multiple injuries including both physical and psychological, multiple physical injuries only, puncture, rupture, severance, sprain, and strain.

Pinnacol provided information for all claims from employees at insured construction firms from January 2012 to December 2022. Data included week and year of claim, zip code of business, injury cause, and gross paid total (e.g., cost of the claim). For each week and year, we summed the number of traumatic injury claims that occurred in each zip code. Similarly, we averaged the cost of the claim over the week and year for each zip code.

To account for potential differences in the "at risk" population for injury in each zip code we used the County Business Patterns (CBP) data from the U.S. Census Bureau. This provided us with an estimate of the number of construction workers in each zip code. CBP data from 2019 was used for all the years in our analysis dataset.

Temperature Data

Temperature data was pulled from Daymet,[13] which provided gridded estimates of temperature for each zip code in the state for the period. Developed in coordination between Oak Ridge National Laboratory, NASA, and the U.S. Department of Energy, more detailed information about Daymet and the data models used to develop the estimates can be found at https://daymet.ornl.gov/. This data was accessed using the R package 'daymetr'.

Daymet data provided daily temperature minimum, daily temperature maximum, and daily average partial pressure of water vapor. We calculated the daily temperature average as the sum of the daily temperature max and daily temperature minimum divided by two. Water vapor pressure was converted from Pascals to Hectopascals (hPa). Saturated vapor pressure (e_s) was calculated using equation 1, where T_{mean} was the observed daily temperature mean in °C. Relative humidity was then calculated using equation 2.

$$e_s = 6.11 * exp(\frac{17.27T_{mean}}{237.3+T_{mean}}) \qquad \text{(Equation 1)}$$

$$RH = \frac{hPA}{e_s} * 100 \qquad \text{(Equation 2)}$$

To create exposure variables that were on the same time scale as the occupational injury data, we averaged each exposure variable over the week. The traumatic injury data and the temperature data were merged using zip code, week, and year.

Statistical Analysis

Our analysis followed a non-linear regression framework. We used a negative binomial distribution with a log link function for injury count to account for the excess numbers of zeros observed. We used a log-linear regression model for cost to adjust for the extreme skewedness of cost data. Both models included an adjustment variable for year of injury and week of injury. The injury count model also adjusted for the CBP estimate. Independent models were run for each of our exposures of interest (average weekly mean temperature, average weekly maximum temperature, average weekly minimum temperature, and average weekly relative humidity). A sensitivity analysis was run assessing the relationships in the meteorological summer (weeks 22-35). All analyses were conducted in R version 4.3.1.

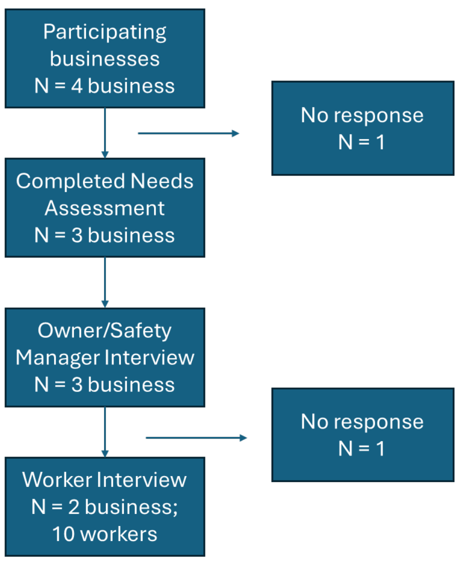
Qualitative Data

Qualitative data collection was a multistep process. First, we identified owners or safety managers who were willing to participate. They were then asked to fill out a heat safety needs assessment that had been developed to capture information about the current practices of small businesses regarding heat safety. After completing the needs assessment, the owner/safety manager was asked to take part in a 30-minute to 1-hour interview. At the conclusion of the interview, the researchers scheduled a time to come out to one of the firm's worksites to conduct additional 10-minute interviews with workers. Owners/safety managers were compensated $50 for their participation and workers were compensated $25.

Small Construction Business Recruitment

We took a multipronged approach to recruiting businesses to participate in this study. First, we presented at the Associated General Contractors of Colorado meeting to introduce the goals of our study and ask for participants. This approach resulted in two participating businesses. Secondly, we identified and solicited study participation through businesses participating in Health Links®, a program that champions health and safety at work. This resulted in an additional participant. Finally, personal networks produced a fourth and final business. Figure 1 provides a CONSORT diagram of participating businesses.

Figure 1. CONSORT diagram of participating businesses.



Interviews

Interview questions with owners/safety managers were informed by the results of the needs assessment. Examples of questions asked included, "*I know you indicated on the survey that you are doing [response from needs assessment] to address heat exposure in the workplace. What was the catalyst for that?*" and *"You indicated that [response from needs assessment] are barriers that you face when trying to address heat exposure in your workplace. I was hoping you could explain to me a little bit about that. Do you have an example?"*.

For worker interviews the goal was to understand their perspective and to see if they were engaging with the policies and programs currently in place. Example questions included "*Do you consider doing work in the heat to be a safety concern? Why or why not?*", "*What do you find is the hardest part about doing your job safely?",* and *"I know your company indicated on the survey that they are doing [insert] to address heat exposure in the workplace. I am interested in if you can expand for me a little bit about what that program looks like."*

All interviews were recorded with permission and transcribed using Notta. Transcriptions were reviewed along with the recordings to verify accuracy.

Qualitative Data Analysis

Our codebook development was guided by three primary questions: (1) heat as a safety concern; (2) adaptation strategies; and (3) barriers and facilitators. We used both inductive and deductive coding. We began with the initial set of codes: "heat," "adaptation," "barrier," "facilitator," "safety," and "productivity." Additional codes were added to the list as commonalities emerged in our initial reading of the transcripts. During a second reading of the transcripts, codes were applied to passages containing, or related to, that code. Subsequent readings facilitated identification of emergent themes.

Case study development

Using the survey data, we summarized for each company the current strength of their heat safety programming and identified potential areas for improvement. We then compared the emergent themes from the interviews between worksites to develop more in-depth case descriptions.

Accomplishments and Results

Quantitative Data

There were 90,977 workers compensation claims for insured construction companies between January 1, 2012, and December 1, 2022. Of these, 83,352 (92%) were considered traumatic injuries. The median weekly average cost of non-zero claims was $1,172 (IQR: $5730.50).

Figure 2 graphically displays the average weekly mean temperature and average weekly injury rate per 100 FTE over the 10 observed years. Cheyenne County (0.5 per 100 FTE), Jackson County (0.3 per 100 FTE), Costilla County (0.2 per 100 FTE), San Juan County (0.2 per 100 FTE) and Hinsdale County (0.1 per 100 FTE) had the highest average weekly injury rates. Baca County (12.4 °C), Otero County (12.2 °C), Bent County (12.1 °C), Prowers County (12.1 °C), and Pueblo County (11.7 °C) had the highest average weekly mean temperatures over the same period. The same six counties had the highest average weekly max temperature.

Figure 2. Average weekly mean temperature (°C) and average weekly injury rate per 100 FTE construction workers by zip code in the state of Colorado, 2012 – 2022.

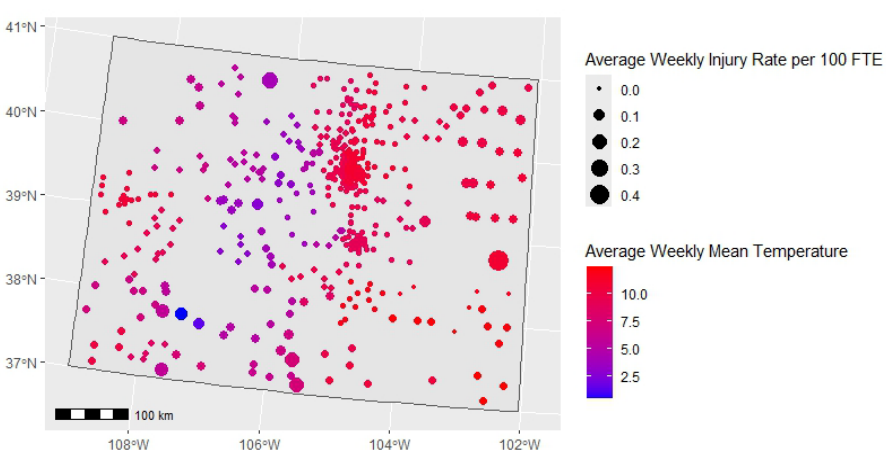
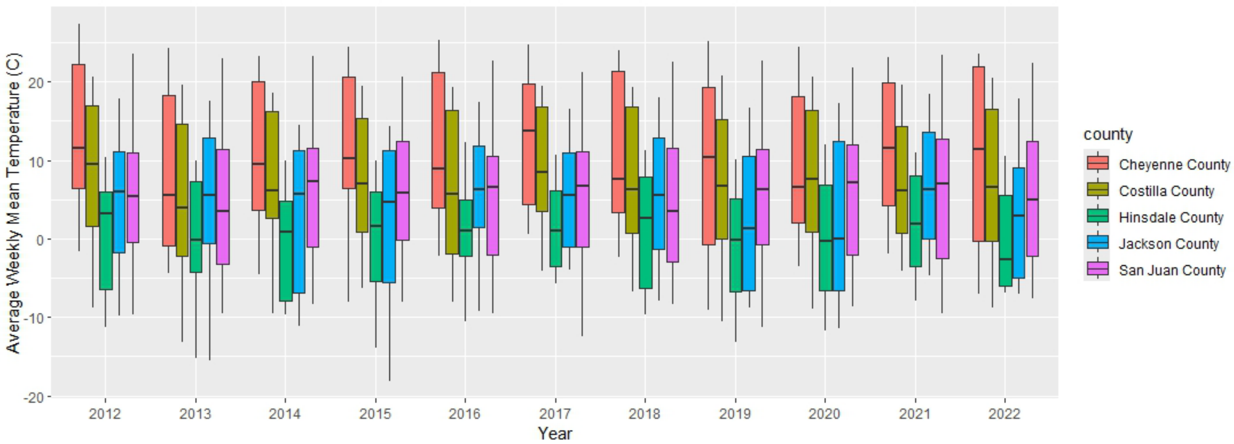


Figure 3 shows the average weekly mean temperature for each year for the five counties with the highest average weekly injury rate over the 10 years. Average weekly median temperatures significantly differed by year (p-value < 0.001) and county (p-value < 0.001).

Figure 3. Annual average weekly mean average temperature (°C) from 2012-2022 for the five counties in Colorado with the highest average weekly injury rate per 100 FTE.



2.6%) in the weekly incident rate of traumatic injury workers' compensation claims among construction workers in Colorado for each 1°C increase in average weekly mean temperature. For each 1°C increase in average weekly mean temperate, the average weekly cost per non-zero cost claim decreased by -0.6% (95% CI: -1.1%, -0.2%). Similar results were observed for weekly average daily maximum and minimum temperatures. No associations were observed with weekly average daily relative humidity. Sensitivity analyses showed similar results when restricting the analysis to only summer months. Table 1 summarizes these findings.

Table 1. Results of estimated percent change in weekly incident rate for workers compensation claims among construction workers in Colorado for each 1°C increase in average weekly temperature. Models adjusted for year and week.

	Weekly Average Daily Temperature	**Weekly Average Daily Max Temperature**	**Weekly Average Daily Minimum Temperature**	**Weekly Average Daily Relative Humidity**
Estimated % change in incident rate, all months	2.4% (2.1%, 2.6%)	1.4% (1.1%, 1.6%)	3.5% (3.2%, 3.8%)	0.07% (-0.01%, 1.5%)
Estimated % change in incident rate, summer months	2.5% (1.9%, 3.1%)	1.6% (1.1%, 2.1%)	3.4% (2.7%, 4.1%)	-0.6% (-0.7%, -0.4%)
Estimated % change in cost per claim*, all months	-0.6% (-1.1%, -0.2%)	-0.4% (-0.8%, -0.01%)	-0.8% (-1.3%, -0.3%)	-0.1% (-0.2%, 0.1%)
Estimated % change in cost per claim*, summer months	-0.5% (-1.5%, 0.4%)	-0.3% (-1.1%, 0.5%)	-0.8% (-1.8%, 0.3%)	-0.1% (-0.4%, 0.1%)

Case Studies

Table 2 summarizes the components of the heat-related illness prevention plans currently in place at the participating organizations.

Table 2. Summary of components of heat-related illness prevention plans currently in place at participating organizations. X indicates the plan currently includes the component.

Component	Company 1	Company 2	Company 3
Heat illness prevention training	X		
Provide water	X	X	
Provide electrolytes	X	X	
Provide restrooms	X	X	
Hydration training	X		
Acclimatization program			
Temperature monitoring	X	X	
Temperature-based work modifications	X		
Rest/cooling center accessible	X	X	
Airconditioning/portable fans accessible	X	X	X
Wearable cooling systems available	X	X	
Emergency preparedness plan (EPP)	X		
Rehearse EPP regularly			

Company 1 was a construction firm that has been operating for 5-9 years. They employ approximately 150 full-time workers. Workers at this company can be found both indoors and outdoors, with and without climate-controlled environments, and involve both sedentary and active roles. This company currently has a heat-related illness prevention plan and designated personnel to oversee it. While heat is not a top safety priority year-round, there is a strong seasonal focus on the hazard. This is supported by their comprehensive heat-illness prevention plan (Table 2).

Workers we interviewed were aware of the hazards related to heat exposure in the workplace and the necessary preventative measures. This knowledge can be attributed to the extensive heat-related safety trainings workers receive. Workers indicated that the company uses weekly toolbox talks as an opportunity to address heat-illness prevention and uses one of their quarterly all-hands safety meetings to "*really try to emphasize on at least spending an hour and a half just straight on heat stress and what we could do more effectively, so we have more additional training outside of the job site.*" All five workers interviewed mentioned the extensive training they received and agreed that this approach is effective: as one said, "*the message is getting across*."

Despite the extensive training, as one worker put it, "*well, sometimes, even though you're given the information, some people choose not to follow*." Interviewed workers at this company agreed that decisions to not follow safety guidance often comes down to productivity demands, noting, "*[workers are] trying to work too fast and not take the proper precautions to get their job done safely. A lot of guys are out here, they want to do good* *work and they want to get the job done. So sometimes, they neglect certain things that keeps them safe when they're doing their job.*"

A strong safety culture at this company tends to offset these demands, with a worker explaining, "*Like, my foreman at the time, he was making sure, like, hey, go take a break. Because we're out in the middle of the sun. There's no shade. So, we work a couple of hours. Take 15 minutes, 10-15 minutes, whatever, and then go back to work*." This was echoed throughout interviews with workers describing that they also feel empowered to take rest breaks when necessary.

Company 2 has been operating for over 10 years and employs approximately 225 full-time workers. They have workers who are active in non-climate-controlled indoor conditions and outdoor worksites. They also have active and sedentary workers in indoor climate-controlled conditions. Although the company agrees that addressing heat stress can lower the risk of other safety concerns, they are neutral on whether heat safety is top priority seasonally, and strongly disagree that it is a top priority year-round.

Three workers (welders and their foreman) and two sub-contractors were interviewed at this worksite. Neither welder indicated that heat was a safety concern. When asked whether they thought heat was a safety concern, they responded, "*Sometimes?*" Probing further, when asked about the additional heat burden of personal protective equipment and if it made them feel especially hot, one welder said, "*I don't, I feel good.*" These opinions are likely attributed to a lack of training received at the company. The foreman described, "*Yeah, usually during the summer we always bring [heat safety] up. It's in one of our safety letters that we do every week, but I really can't say there's been too much training about it.*" When the workers were asked directly if they received safety training, their response was simply "*No.*"

Despite a lack of training, workers were aware of heat safety measures. For example, one worker stated, "*I mean, you're thirsty, you need to drink water, you know, to lose the heat and you say you're going to take a break, so you can go.*" However, the foreman reflected that while workers know what to do, they do not always comply, noting, "*Well, I mean, the problem is, it's our iron workers are just kind of hardheaded. A lot of them are just hardheaded. They just want to say they're good, they're good. That's why you always push drinking water and stuff on the people*." One of the sub-contractors we spoke with further highlighted the need for workers to look out for one another, stating, "*We always like to have our guys watch out for one another because a lot of times guys being guys and being in the trade…most guys don't like to be the one to say, 'I can't do this' and stuff like that so [they keep] going. So, watching out for each other is another big aspect that we focus on for our company because there's definitely been times where I'm like, 'Hey like you need to go take a break' and they're like, 'I'm good, I'm good.' I'm like, 'I'm not asking you, I'm telling you.'*"

Company 3 was a construction firm that has been in operation for 1-4 years. They employ two contract workers. Workers at this company can be found both indoors and outdoors, with and without climate-controlled environments, and have both sedentary and active roles. This company does not have a heat-related illness prevention plan and does not see heat to be an issue in their workplace.

Key Areas for Further Engagement

Sub-contractors – One common discussion point with Company 1 was sub-contractor safety on the worksite. While workers at Company 1 were engaged with heat safety precautions, many noted that sub-contractors did not always follow the same practices. As one worker noted, "*Maybe they needed more, like more training for their companies like we usually get in our company.*" [Worker, Company 1]. Notably, speaking with subcontractors onsite with Company 2 highlighted the differences in training and resources provided to workers on the same jobsite. For example, at Company 1 when asked if wearable cooling technology was provided to everyone on site they responded, "*Typically [only] for our guys. Because it'd be really expensive to provide it* *for everybody on site.*" There is a need to further explore strategies to have the same safety programs available to all workers at a worksite.

Effectiveness of training – We received mixed messages on the effectiveness of training. When talking about the toolbox talks, one worker stated, "*I mean, honestly those morning meetings people don't really listen to most of the **** that's being said, it's more of a formality.*" [Sub, Company 2] However, a worker at Company 1 thought the toolbox talks were the single most effective component of the heat safety program, stating, "*I think probably the toolbox talks are the most effective. Just getting out there and explaining it to everybody in the field.*" There is a need to further explore what makes for an engaging and effective heat safety training.

Safety Culture - One common theme that emerged was the importance of looking out for one another when it comes to heat safety. Heat safety in the workplace is not the sole responsibility of the worker. As one foreman described, acknowledging the role that management plays, "*the more important thing is to have your management and your guys looking out for each other.*" [Sub Foreman, Company 2] There is a need to further explore strategies to develop a strong culture of safety, especially as it pertains to heat.

Unanticipated problems

Due to the structure of the data that Pinnacol was able to provide (weekly aggregate counts rather than individual level), we were unable to implement the proposed distributed lagged non-linear models (DLNM). However, we were able to run negative binomial models for weekly injury count. While this analytic method differed slightly from the DLNM, it still allowed us to determine the association between increasing temperatures and the risk of occupational injuries among construction workers in the state of Colorado. The biggest issue this project faced was recruitment of small businesses. Only one participating business met the definition of small construction firm (less than 20 employees). While we did not meet our target enrollment of 5 businesses, we feel like in our 10 interviews with workers we reached consensus. Additionally, our results may be biased as the two companies for which we were able to interview workers already had fairly comprehensive heat safety programs in place. The results from those interviews presented here may not be representative of workers at companies who do not have such programs.

Dissemination & Future Plans

Results from this project were used to inform the workshop: "Heat Stress Preparedness: Practical Strategies for Workplace Safety" hosted by AIHA Rocky Mountain Section and the Colorado Chapter of ASSP. We are currently preparing a manuscript to describe the findings of this study. We have been in contact with local policy makers to identify how this research may be beneficial for future policy development (CO HB25-1286: Protecting Workers from Extreme Temperatures). There are two future grants that are currently in preparation that will utilize the findings from this study. Both grants will be submitted to the NIH. The goal of these grants will be to further explore the mechanisms through which heat acts as a hazard multiplier on occupational injuries and further assess facilitators and barriers to implementation of heat safety programming at work.

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