Received: 21 September 2019 | Revised: 10 December 2019 | Accepted: 14 January 2020

DOI: 10.1002/ajim.23092

RESEARCH ARTICLE

AMERICAN JOURNAL OF INDUSTRIAL MEDICINE WILEY

Heat related illness among workers in Washington State: A descriptive study using workers' compensation claims, 2006-2017

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Abstract

Background: Heat related illness (HRI) places a significant burden on the health and safety of working populations and its impacts will likely increase with climate change. The aim of this study was to characterize the demographic and occupational characteristics of Washington workers who suffered from HRI from 2006 to 2017 using workers' compensation claims data.

Methods: We used Washington workers' compensation data linked to weather station data to identify cases of work-related HRI. We utilized Occupational Injury and Illness Classification System codes, International Classification of Diseases 9/10 codes, and medical review to identify accepted and rejected Washington State (WA) workers' compensation claims for HRI from 2006 to 2017. We estimated rates of HRI by industry and evaluated patterns by ambient temperature.

Results: We detected 918 confirmed Washington workers' compensation HRI claims from 2006 to 2017, 654 were accepted and 264 were rejected. Public Administration had the highest third quarter rate (131.3 per 100 000 full time employees [FTE]), followed by Agriculture, Forestry, Fishing, and Hunting (102.6 per 100 000 FTE). The median maximum daytime temperature was below the Washington heat rule threshold for 45% of the accepted HRI claims. Latinos were estimated to be overrepresented in HRI cases.

Conclusion: The WA heat rule threshold may not be adequately protecting workers and racial disparities are present in occupational HRI. Employers should take additional precautions to prevent HRI depending on the intensity of heat exposure. States without heat rules and with large industry sectors disproportionately affected by HRI should consider regulations to protect outdoor workers in the face of more frequent and extreme heat waves.

KEYWORDS

climate change, heat exposure, heat-related illness, heat stress, workers' compensation

1 | BACKGROUND

The incidence of heat related illness (HRI) such as heat stroke and heat exhaustion will only increase with the increasing frequency and intensity of extreme heat events projected with climate change.[1] Exposure to heat in occupational settings remains a critical area for public health intervention and research as demonstrated by the preventable mortality among workers from HRI. Between 2011 and

2017 the U.S. Bureau of Labor Statistics reported that a total of 252 people died on the job due to environmental heat exposure.[2] The World Health Organization declared severe weather resulting from climate change as one of the leading global health threats of the 21st century, and exposure to extreme heat is already the most common cause of weather-related deaths in the United States.[3,4] Researchers predict that the intensity and frequency of hotter temperatures and episodic heatwaves will become more common.[3,5] This means that the incidence of HRI will likely increase if workers continue to conduct their work in increasingly hotter environments without adequate controls.[6] These projected changes in climate elevate the importance of examining the public health implications of exposure to environmental heat in occupational settings. Recent studies have explored HRI in the context of climate change but have not examined both weather data and occupational HRI trends over time in a defined population.[7]

HRI is a spectrum of illnesses ranging from heat rash, heat cramps, and heat syncope (fainting) to more severe illness such as heat exhaustion and heat stroke, which can lead to organ failure and death. HRIs occur when a combination of exposure to environmental heat and the generation of heat from within the body due to physical exertion exceeds the capacity of the human body to dissipate heat. Exposure to higher ambient heat has also been linked to an increased risk of traumatic injuries among workers.[8–10]

In occupational health, HRI has a broad impact occurring across many industrial sectors. A previous descriptive study in Washington State (WA) from 1995 to 2005 reported the highest rates of HRI in Agriculture, Forestry, Fishing and Hunting, Construction, and Public Administration industry sectors.[11,12] Specific industries within Public Administration that had the highest rates of HRI included Fire Protection and the Administration of Conservation Programs.[11] All of these industries have a significant portion of employees who labor outdoors and face exposure to environmental heat. Most studies on occupational HRI have focused on agricultural workers, and for good reason, as the rate of heat related deaths among agricultural workers is 20 times higher than the rate for civilian workers.[13] Nationwide, about a quarter of HRI deaths have been reported in the Agriculture, Forestry, Fishing, and Hunting industrial sector which comprises a significant portion of the economy in WA. Prior studies among agricultural workers have described a range of self-reported prevalence of HRI symptoms, from 35% of workers reporting HRI in the previous 3 months in one study to 72% of workers reporting heat associated symptoms in the previous week.[14,15] The variable prevalence estimates of HRI symptoms can be partially attributed to multiple factors including differences in symptom recognition, HRI reporting, and varying levels of occupational and environmental exposures across sample populations.

There are a variety of factors associated with an increased risk of suffering from work-related HRI. Age, wage payment systems (ie, piece rate), use of personal protective equipment (PPE), exposure to direct sunlight, prior experience, acclimatization, and the presence of worker protections can all modify occupational risk of HRI.[11,13,16] Those who are older than 65 or younger than 15 have an increased risk of suffering from HRI among the general population.[17] Previous studies found the distribution of occupational HRI tends to be elevated among younger workers between the ages of 18 and 24.[11] People with less economic security or those that live in substandard housing, such as many agricultural workers, often do not return to a climate controlled environment after working in elevated temperatures throughout the day which increases the incidence of HRI.[18] The documented elevated rate of HRI among agricultural and construction workers combined with the fact that many employed in these industries identify as Latino also bears implications for efforts to improve health equity.

Although the National Institute of Occupational Safety and Health (NIOSH) has shown that at 85°F and above, workers in normal clothing are at an increased risk of HRI, only two US States have workplace safety regulations to protect outdoor workers from HRI: Washington and California, and one state, Minnesota, has a heat rule to protect indoor workers.[19,20] WA's regulations were created in 2007 in response to concerns voiced by farmworker advocates after the death of an agriculture worker in eastern Washington.[21] The Washington State Department of Labor and Industries set an outdoor temperature regulatory threshold or "action level" at 89°F for workers wearing clothing other than double layer woven clothes or nonbreathing clothes such as vapor barrier clothing.[21,22] Both California and Washington's heat regulations require training and for water to be made available to workers. California's heat rule also includes mandatory rest breaks and access to shade, both of which are demonstrated to be protective against HRI.[23,24]

Despite the significant burden of HRI among workers and the increasing threat of adverse health outcomes with climate change, the epidemiology of occupational HRI remains poorly studied.[25] There are few public health surveillance systems capturing HRI in working populations. More specifically, the rates of HRI in WA have not been examined since the heat rule was first implemented in 2007.

This descriptive study seeks to characterize the demographic and occupational characteristics of Washington workers who suffered from HRI from 2006 to 2017. It uses WA workers' compensation claims data to identify cases of occupational HRI and examine the trends over time and in relation to local climate data.

2 | METHODS

WA has a single payer workers' compensation insurance system. Employers within the state are mandated to purchase workers' compensation insurance through the Washington State Department of Labor and Industries' (L&I) State Fund (SF) unless they meet the statutory and financial requirements to self-insure or are covered by other workers' compensation systems (eg, the federal government). Workers' compensation insurance claim and employer data are stored within L&I databases and have been described previously in detail.[26] The study was conducted by a public health authority with statutory obligations to compile statistics and data for the

control of occupational injuries and illness which includes occupational HRI. The study is public health practice and is exempt from IRB review.

2.1 | Identification of suspected HRI cases

We identified HRI claims from the Occupational Injury and Illness Classification System (OIICS) codes, and from International Classification of Diseases-9/10 Clinical Modification (ICD-9/10-CM) codes (WA L&I switched from using ICD-9 to ICD-10 codes on 1 October 2015),[27] OIICS codes are assigned based on a narrative submitted by the worker describing the injury or illness and the physician's diagnosis, objective findings, and treatment plan on the workers' compensation claim initiation form. ICD codes are designated by the health care provider on the initial claim form and then throughout the life of claim from bills for payment submitted by health care providers, hospitals, pharmacies, and by claim adjudicators for allowed medical diagnoses.

Suspected HRI claims were identified in the workers' compensation databases by using specific OIICS codes and ICD9/10 codes as described in Table S1. When any one OIICS or ICD 9/10 was associated with a workers' compensation claim, the unique claim identification number, OIICS codes, and incident narrative from the claim initiation form, and dates of service associated with the HRI-related diagnoses were retrieved. The cases were extracted on 10 January 2019 and were limited to claims with a date of illness from 1 January 2006 through 31 December 2017. The date of illness refers to the date reported by the worker on the claim initiation form in the field labeled "injury date," and is assumed to be the date the worker experienced the HRI. All claims were retrieved regardless of whether the claim was accepted or rejected for workers' compensation benefits. Only SF claims were analyzed because ICD 9/10 CM codes are not available for self-insured claims.

2.2 | Case confirmation

A total of 6538 claims were suspected HRI claims (see Figure 1). Of those, 316 were excluded because the incident occurred outside of the jurisdiction of the Washington workers' compensation system (eg, out of state workers and federal employees). An additional 1995 were excluded because the service date of the first medical bill associated with treatment of dehydration or kidney failure was not within 1 day of the date of illness. This exclusion was necessary because ICD 9/10 codes for dehydration or kidney failure are often associated with medical bills for a large number of non-HRI claims as described below.

Suspected claims were confirmed as HRI cases when the health care provider attributed the worker's illness to exposure to environmental heat on the claim initiation form or within the medical record. Similar to the above exclusion, when either dehydration or kidney failure ICD 9/10 codes were the sole identifiers of a suspected HRI case, these claims were almost exclusively false positive claims for HRI. Of the 2584 claims where dehydration (within 1 day of illness) was the sole identifying data element for HRI, we sampled 293 claims and only eight met the case definition. Likewise, a sample of 79 claims for kidney failure yielded only two claims that were positive for HRI. We subsequently excluded all claims where either dehydration (n = 2584) or kidney failure (n = 202) were the sole means for case identification. For the remaining suspected HRI claims, two researchers (D.B., A.R.) independently reviewed the claim record to determine if it was an HRI case. Of the 1441 suspected HRI cases, by consensus of the two reviewers, 918 were confirmed as HRI cases.

Following case confirmation, additional data were retrieved for each claim, including the claimant's date of birth, the date and hour of illness, the North American Industrial Classification System (NAICS) industry code for the employer, business location, the claim status

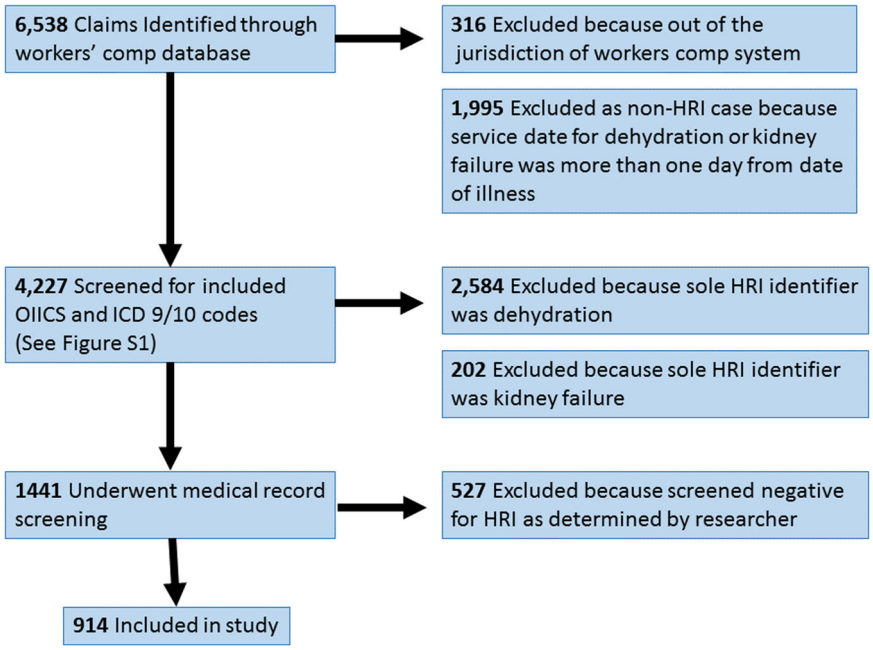

FIGURE 1 Exclusion criteria for heat related illness case detection [Color figure can be viewed at wileyonlinelibrary.com]

code, the claimant's occupation code according to the 2000 Standard Occupational Classification system, and the cost of the claim. For comparison purposes, similar data were collected for all accepted SF claims during the study period. Workers' compensation claim costs represent those paid during the course of the claim. All HRI claims in this study were closed, so costs are unlikely to further accrue. Indirect costs to employers and workers and the administrative costs of managing the claim are not included in the claim costs. We extracted both accepted and rejected claims. Accepted claims are either noncompensable (medical aid only) or compensable. Compensable claims are those eligible for wage replacement, death, or disability benefits. A claim qualifies for wage replacement, that is, time loss payments, if the worker is unable to work on the fourth calendar day following a three calendar day waiting period. Both compensable and noncompensable claims were included in the study. We did not examine if there were multiple claims from a single claimant.

To characterize the race and ethnicity of HRI claimants we used both the preferred language of the claimant as indicated on the workers' compensation claim form and an imputation method called the Bayesian Improved Surname Geocoding (BISG) method to assign probability estimates for the claimant's race and ethnicity.[28] BISG assigns each worker a set of probabilities for each race and ethnicity category, summing to one based on Census data for distributions of race and ethnicities associated with the worker's last name and census block group. Totals for each race and ethnic category were summed across all claims after probability estimations were assigned to all confirmed HRI claims. This produced an estimate for the number and percent of claimants in each racial and ethnic category. We compared these percentages to the racial and ethnic distribution of workers in WA, as reported by the CDC Employed Labor Force estimates query system.

Temperature was assigned to each claim record by matching weather station temperature data to the estimated work location. Temperature data were obtained from three weather data repositories: the Federal Aviation Administration, the National Oceanic and Atmospheric Administration, and AgWeatherNet.[29–31] Weather data were matched to geocoded addresses using a previously described method.[9] We prioritized the available address information on the claim to identify the nearest available weather station in relation to the (a) reported incident location, (b) employer's business location address, if matched to the treating provider's county, (c) treating provider's address, and (d) employer's business location address regardless of the treating providers address. The median distance from the address to the linked weather station was 3.28 miles (interquartile range [IQR]: 1.99-5.49 miles). Temperature data retrieved were the maximum temperature on the date of illness, the temperature at the hour of illness, and the maximum temperature over the 3 days preceding the illness. Researchers chose to only use ambient temperature as a metric for heat because this is the same standard used by the WA heat rule and humidity measures were not consistently available across all temperature data points. Researchers used a quarterly statewide temperature anomaly measure, defined as the average departure from the mean temperature, to examine statewide trends in temperature in relation to third quarter incidence rates. Based on the availability of weather data, we were able to link all 918 claims to a maximum temperature for the 3 days preceding the claim, 905 observations to the maximum temperature the day of the illness, and 793 claims to the maximum temperature at hour of illness.

Employers report the total number of hours worked by their employees to L&I. Each employer account is assigned a six-digit NAICS code based on the primary economic activity of the business. By using the assigned NAICS code for the employer accounts with an HRI claim and the aggregated reported hours for accounts assigned the same NAICS code, we calculated HRI incidence rates by industry. Employers within the Washington SF report the cumulative number of hours worked by their employees on a quarterly basis. Time periods for the quarterly reporting were first quarter, January-March; second quarter, April-June; third quarter, July-September; and fourth quarter, October-December. Claim incidence rates were determined by assuming that a full time employees (FTE) is equivalent to 2000 work hours.

All descriptive analyses were performed with STATA Version 15.1 (StataCorp LLC). Differences in proportions for the distribution of demographic characteristics between HRI claims and all SF claims were analyzed using two proportion *z* tests. Analysis of variance was used to measure differences in acceptance rates by industry. The relationship between yearly third quarter HRI rates and temperature anomaly was calculated using the Pearson correlation coefficient.

3 | RESULTS

3.1 | Demographics and claim characteristics

A total of 918 Washington SF workers' compensation confirmed HRI cases occurred between 2006 and 2017 (see Table 1). Of these claims, 654 were accepted and 264 were rejected. There was higher percentage of males among accepted HRI claims at 82% vs 68% for all SF claims ($P < .001$; 95% confidence interval [CI] = 0.11-0.17). There was also a greater proportion of HRI cases detected in younger age groups. Among the accepted HRI claims, 23% were in the 18 to 24 age group compared with the 18% among all SF claims ($P = .002$; 95% CI = 0.02-0.08). Thirteen percent of HRI claims indicated Spanish as their preferred language compared with 11% of all SF claims ($P = .038$). A larger proportion of HRI claims (91%) were noncompensable (medical costs only) compared to all SF claims (73%). HRI claims, like all claim cost data, is right skewed due to a small number of high cost claims. The median cost for HRI claims was $909 (IQR: $537-$1502) which is $109 dollars higher than the median cost for all SF claims. There was one fatal HRI case from 2006 to 2017. Using the BISG method, we estimated a racial and ethnic probability value for 791 of the confirmed HRI claims. Using these probabilities, the racial and ethnic distributions of HRI claimants was 63% white, followed by 21% Latinos and 8% black/African American. The estimated racial and ethnic distribution differed from the overall

TABLE 1 Characteristics of Washington SF claims for HRI compared with all Washington SF claims (2006-2017)

	Accepted HRI claims only *N* = 654	All SF accepted claims *N* = 1 170 370	Rejected HRI claims only *N* = 264
Male, %	82.0	67.5	74.6
Age group, %	*N* = 647	*N* = 1 155 165	*N* = 256
14-17	1.6	0.7	2.3
18-24	23.2	18.4	19.1
25-34	27.7	29.6	30.1
35-44	24.0	25.4	21.1
45-54	15.0	24.0	18.0
55-64	8.0	14.2	8.2
65+	0.6	2.4	1.2
Preferred language, %			
Spanish preferred	13.0	10.5	14.0
All accepted claims, $			
Average cost	2669	4276	…
Median cost	909	800	…
Noncompensable claims only, $	*N* = 595	*N* = 859 627	…
Average cost	1175	1131	…
Median cost	876.9	560.0	…
Compensable claims only, $[a]	*N* = 40	*N* = 310 743	…
Average cost	6713	12 959	…
Median cost	2888	6660	…
Time loss claims only, d[b]	*N* = 38	*N* = 253 738	…
Average time loss per claim	93	189	…
Median time loss	13	54	…

Abbreviations: HRI, heat-related illness; SF, state fund.
[a]Compensable claim includes claims with the following: payment for time loss from work, and injured worker kept on salary, an injured worker receiving a disability award or a fatality.
[b]Uses 7-d week despite workweek schedule.

state workforce where racial composition in 2017 was 81% white, 13% Latino, and 4% black/African American.[32]

3.2 | Temporal and locational information

HRI claims were distributed unevenly across month and time of day with the majority of accepted HRI claims (76%) occurring in the third quarter (July-September). July had the greatest proportion of claims (48%), and most claims listed the hour of illness between noon and 5 PM. The number of accepted claims was split evenly between eastern Washington ($n = 334$) and western Washington ($n = 320$). The estimated yearly rate stratified by region indicated that rates in eastern Washington were 2 to 10 times higher than rates in western Washington depending on the year and had more variation between years. The median maximum day temperature for HRI cases in eastern Washington (93.9°F) was higher than the median maximum day temperature for western Washington HRI cases (86.4°F). The distribution of industry sectors also differed between eastern and western Washington. About 75% of claims from the Agriculture, Forestry, Fishing, and Hunting industry sector were from eastern Washington whereas the Construction sector was split more evenly with 55% occurring in western Washington and 45% in eastern Washington.

3.3 | Industry and occupation information

The Construction industry sector had the largest number of accepted HRI claims from 2006 to 2017 and comprised over a quarter of all accepted HRI claims (26%) (see Table 2). The second most represented sector was Agriculture, Forestry, Fishing, and Hunting with 17% of accepted HRI claims. However, agriculture had the highest annual rate of HRI claims of 13.0 per 100 000 FTE and a third quarter rate of 102.6 per 100 000 FTE. Other sectors with the highest HRI claim rate were Public Administration, Administrative and Support and Waste Management and Remediation Services (eg, landscapers, temporary help services, and convention and visitor bureau workers), Manufacturing, Wholesale Trade, and Accommodation and Food Services. Detailed industries, as defined by the six-digit NAICS code with the highest number of HRI cases, included Fire Protection (33 claims) and Farm Labor Contractors and Crew Leaders (24 claims) (see Table 3). Farm labor contractors also includes workers participating in the H-2A visa program. Farmworkers and Laborers were the occupation with the highest number of accepted HRI cases (77 claims) followed by Firefighters (60 claims).

3.4 | Temperature data

The maximum hour, maximum day, and maximum 3-day temperatures for HRI claims each had a broad range and all were left skewed with outliers in the lower temperatures (see Figure 2). The low temperature outliers are likely due to the inclusion of HRI cases that occurred indoors, where the worker used PPE, or when the worker was performing heavy physical work in cooler temperatures. The median observed temperature was highest for the maximum 3-day temperature (92.5°F), followed by maximum day temperature (90.8°F) and maximum hour temperature (88.2°F). The median maximum day temperature varied by industry ($F(22, 624) = 2.59$, $P < .001$). The median temperatures for both the maximum day and maximum 3-day are above the WA heat rule threshold of 89°F, whereas the median maximum hour temperature fell below the threshold. Figure 3 shows the third quarter rate of all HRI claims and the number of third quarter HRI claims by year. The years that had an increase in the HRI third quarter rate corresponded with years WA experienced hotter than normal temperatures in the third quarter, as recorded by the National Oceanic and Atmospheric Administration statewide temperature anomaly measure (Figure 4). We observed a positive and nearly significant relationship between hotter third quarters and the rate of HRI in WA (correlation coefficient: 0.52; $P = .08$; $n = 12$).

TABLE 2 Washington State accepted state fund workers compensation annual and third quarter claim rate for HRI by NAICS industry sector (two-digit code) with greater than 11 claims (2006-2017)

Industry sector name (NAICS)	# Accepted HRI claims, *N* = 654, %	HRI claim rate[a]	Median max daytime temperature, °F	# HRI third quarter claims, %[b]	Third quarter claim rate	# Rejected HRI claims, *N* = 264	Industry rejection percentage
Construction (23)	170 (26.0)	10.8	89.9	124 (25.1)	70.0	61	26.4
Agriculture, Forestry, Fishing, and Hunting (11)	111 (17.0)	13.0	93.0	81 (16.4)	102.6	46	29.3
Public Administration (92)	94 (14.4)	10.3	86.8	73 (14.2)	131.3	15	13.8
Administrative and Support and Waste Management and remediation Services (56)	58 (8.9)	4.6	86.8	48 (9.7)	61.5	29	33.3
Manufacturing (31-33)	55 (8.4)	3.6	95.0	44 (9.0)	35.3	22	28.6
Wholesale Trade (42)	33 (5.1)	2.8	92.0	31 (6.3)	44.9	8	19.5
Accommodation and Food Services (72)	30 (4.6)	1.7	86.3	18 (3.6)	16.3	17	36.2
Retail Trade (44-45)	23 (3.5)	1.1	93.5	15 (3.0)	13.6	16	41.0
Transportation and Warehousing (48-49)	22 (3.4)	3.8	91.0	14 (2.8)	27.1	12	35.3
Other service—except public administration (81)	12 (1.8)	1.3	91.0	11 (2.2)	22.5	7	63.2
All other NAICS sector categories	46 (7.0)	…		36 (7.2)	…	31	

Abbreviations: HRI, heat-related illness; NAICS, North American Industrial Classification.

[a]Rate per 100 000 full time employees.

[b]Third quarter comprises of July, August, and September.

TABLE 3 Washington State accepted state fund workers compensation annual and third quarter claim rate for HRI by NAICS industry (six-digit code) with greater than 11 claims for (2006-2017)

Industry sector name (NAICS)	# HRI claims, %	HRI claim rate[a]	Median max daytime temperature, °F	# HRI third quarter claims, %[b]	Third quarter claim rate
Fire Protection (922160)	33 (5.1)	60.0	80.8	24 (4.9)	394.6
Farm Labor Contractors and Crew Leaders (115115)	24 (3.1)	77.3	96.1	19 (3.8)	600.9
Other General Government Support (921190)	20 (3.1)	12.9	92.4	14 (2.8)	113.8
Site Preparation Contractors (238910)	18 (2.8)	25.2	91.9	16 (3.2)	232.1
Poured Concrete Foundation and Structure Contractors (238110)	17 (2.6)	31.6	89.4	11 (2.2)	172.3
Administration of Conservation Programs (924120)	16 (2.6)	28.2	93.2	13 (2.6)	282.7
Other Noncitrus Fruit Farming (111339)	15 (2.3)	13.7	88.9	10 (2.0)	100.9
Commercial and Institutional Building Construction (236220)	15 (2.3)	13.2	92.2	14 (2.8)	122.3
Roofing Contractors (238160)	15 (2.3)	29.0	86.2	11 (2.2)	114.0
Highway, Street, and Bridge Construction (237310)	13 (2.0)	23.6	88.7	9 (1.8)	167.3
All Other Specialty Trade Contractors (238990)	13 (2.0)	20.1	89.2	9 (1.8)	110.9
Temporary Help Services (561320)	13 (2.0)	4.0	90.0	13 (2.6)	54.9
Structural Steel and Precast Concrete Contractors (238120)	12 (1.8)	54.2	87.6	5 (1.0)	134.0
Plumbing, Heating, and Air-Conditioning Contractors (238220)	12 (1.8)	5.7	90.7	7 (1.4)	30.4
Landscaping Services (561730)	12 (1.8)	9.1	86.8	6 (1.2)	36.7
All other industries	343 (52.4)	…	…	265 (53.5)	…

Abbreviations: HRI, heat-related illness; NAICS, North American Industrial Classification.

[a]Rate per 100 000 full time employees.

[b]Third quarter comprises of July, August, and September.

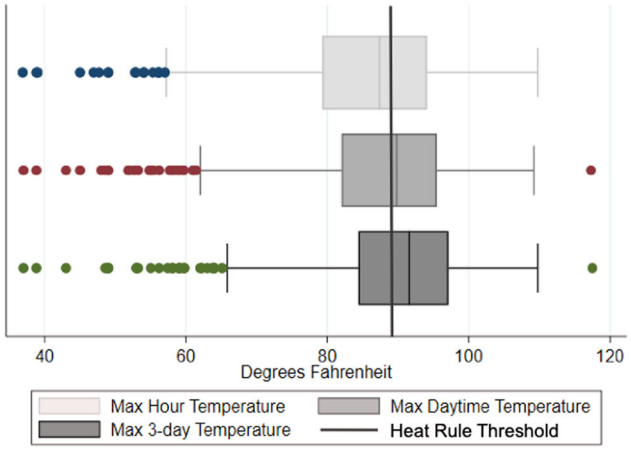

FIGURE 2 Temperature data for all included heat-related illness claims in degrees Fahrenheit (2006-2017) [Color figure can be viewed at wileyonlinelibrary.com]

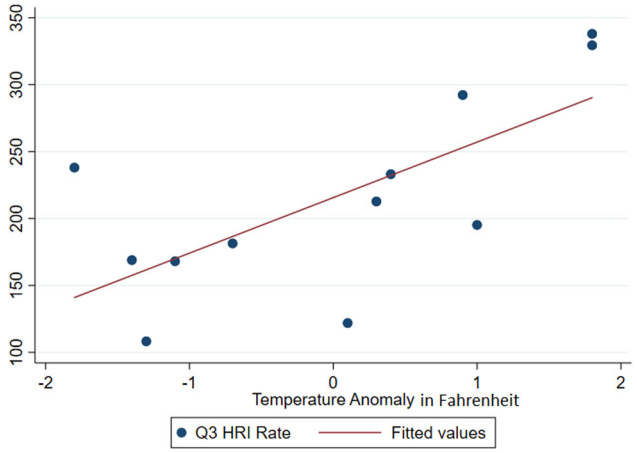

FIGURE 4 Correlation between Q3 claim rate and Washington temperature anomaly by year during the third quarter. HRI, heat-related illness [Color figure can be viewed at wileyonlinelibrary.com]

3.5 | Accepted vs rejected

The gender and age distribution between accepted and rejected HRI claims were similar, as well as the preferred language. The most common reason for rejection among the HRI claims was that there was no definite proof of a specific injury or illness at a definite time and place in the course of employment. There was a difference in the distribution of accepted vs rejected claims based on industry sector ($P = .027$). For HRI claims filed from people who worked in Public Administration (eg, Fire Protection), 86% of the detected HRI claims were accepted. In the Administrative and Support and Waste Management and Remediation Services sector (eg, Landscapers), only 67% of the detected HRI claims were accepted. About 70% of claims from Agriculture, Forestry, Fishing, and Hunting sector were accepted.

4 | DISCUSSION

The findings of this study align with previous findings examining occupational HRI.[11] The overrepresentation of young males among the cases is similar to prior epidemiological reports regarding occupational HRI and the previous descriptive study examining HRI in WA workers from 1995 to 2005.[11,33] The five industry sectors with the highest rates of HRI remain the same as those reported in the prior descriptive study. Both the annual claim rates for the Public Administration sector and Construction sector were similar to last study. However, there was a twofold increase in the annual claim rate for the Agriculture sector compared with the previous study. We found that the median maximum day temperature at which accepted HRI cases are occurring was higher (90°F) than reported in the previous study (85°F).

Although the heat rule in WA is meant to protect workers, our results estimate 45% of HRI claims happened on days where the maximum temperature did not reach the 89°F heat rule action level. This could be due to the simplistic nature of the heat rule as it does not consider other environmental factors, differences in work rates, or use of PPE. In addition, we see a strong correlation between hotter summers and a higher rate of HRI in the third quarter among workers in WA. These higher rates are not impacting all racial and ethnic groups equally and that Latinos and black workers are likely overrepresented among HRI cases in the state.

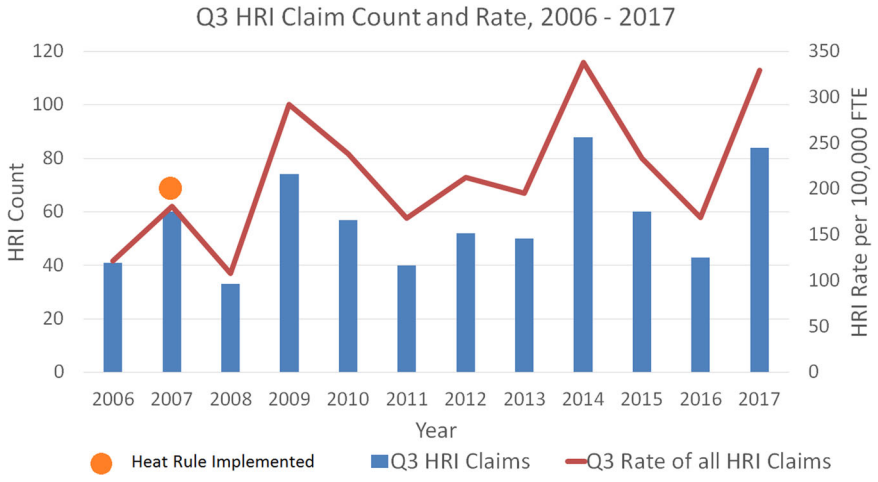

FIGURE 3 Third quarter HRI claim count and claim rate (2006-2017). HRI, heat-related illness [Color figure can be viewed at wileyonlinelibrary.com]

The fact that a large percentage of HRI cases occur at a temperature below the action level suggests that the current heat rule may be insufficient in protecting workers from HRI. In addition, we observe claim rate differences based on the geographical distribution of employment, confirming there is variation in worker risk likely due to the climate differences between eastern and western Washington. We also observed a difference in the distribution of industry between eastern and western Washington. We found a large number of agricultural claims in eastern Washington and a large number of construction claims in western Washington. Both industries have high rates of HRI but median maximum daytime temperature for claims in eastern Washington was higher. This indicates that the warmer climate in eastern Washington is a likely cause of its elevated rates. Given the variation across geographical regions, employers should customize their accident prevention programs to recognize the hazards of heat exposure at temperatures lower than the mandated action levels. Such customization in an employer's accident prevention program could account for the physical demands of the work, the use of protective clothing and other unique workplace hazards that could increase risk of HRI.

There is a statistically significant difference in the proportion of claims that happen below the heat rule threshold between eastern and western Washington ($P < .001$). In addition, estimated rates for eastern Washington HRI claims were significantly higher than the rate in western Washington and varied greatly by year. We see this regional difference reflected in the median maximum daytime temperature for detected HRI claims. Western Washington claims had a median temperature of 86.4°F, and claims filed in eastern Washington had a median temperature of 93.9°F. The difference in median maximum daytime temperatures for HRI claimants when comparing the two sides of the state may also be due to a lack of acclimatization among workers in western Washington. Workers in western Washington experience infrequent heat waves with intermittent periods of lower temperatures. These weather patterns do not allow workers in western Washington to acclimatize to working at their accustomed rates at higher temperatures.[34] In contrast, higher daytime temperatures that are more common in eastern Washington, meaning workers are more likely to be acclimatized if they have already been laboring in those higher temperature for at least 5 to 10 days. This difference in weather patterns suggests that employers may need to tailor HRI prevention strategies to their local environment. In western Washington, prevention response should be informed by weather forecasts predicting heat waves or significant variation in environmental temperatures and how they correspond to the physical demands of work tasks. In eastern Washington, safe workplace policies like mandating access to cooling mechanisms such as shade, and other long-term changes may be more important for lowering the rates of HRI.

We observed multiple years in the study period where both the rate and count of HRI increased and climate projections indicate that WA can expect hotter summers in the future. Without further controls and adaptation, the rate of occupational HRI will increase. Previous studies have also reported an expected increase in mortality among outdoor workers due to higher temperatures.[35–37] Sudden multiday heat events also pose a significant threat to the health and well-being of workers because there is often no chance for workers to acclimatize to hotter temperatures.[38]

Occupational HRI is unique because both the exertional workload and the environmental conditions such as ambient temperature, solar radiation, humidity, and wind speed contribute to a workers risk of HRI. Previous research has found that this exertion risk is modified by the previous days' exposure.[39] This creates a cumulative effect from both temperature and exertion. Of the three measures collected for temperature exposure the maximum 3 day had the highest median. This suggests that many of these incidents happened during a multiday heat event rather than a single day of elevated temperature. This finding aligns with research showing that consecutive days of heat exposure has a cumulative effect in increasing the likelihood of HRI if an individual does not have access to adequate cooling strategies.[38] With the increasing frequency of heat waves and hotter summers, we should expect to see more occupational injuries overall. Higher incidence of occupational injuries is associated with higher ambient temperatures for temperature sensitive industries such as Construction, Agriculture, Forestry, and Utility Servicing.[8,9,40,41]

Racial and ethnic minorities in WA are more likely to face environmental exposures that place them at a greater risk of HRI. Currently, in Washington's workers' compensation data the best proxy measure for estimating the ethnicity of affected workers is the preferred language indicated on the claim initiation form. We see that among all detected HRI claims, 13.3% of claimants indicated Spanish as their preferred language. This is useful information to indicate the need for non-English materials in educational and prevention campaigns. However, our data suggest it is an inadequate surrogate for estimating the racial and ethnic composition of HRI claimants. When we used the BISG to estimate the racial and ethnic composition of detected HRI cases, we estimated that about 21% of the claimants identified as Latino. The BISG method is considered to be “excellent” at predicting Latino ethnicity in both males and females.[28] As of 2016, only 12.1% of WA's workforce identifies as Latino, indicating that HRI is likely disproportionally affecting Latino workers in WA.[32] Workers' compensation data likely provides an underestimation as previous research has found that Hispanic workers were less likely to file workers' compensation claim for nonfatal injuries due to fear of reprisal from their employer.[42]

This finding aligns with work by Gronlund and others that found people of color were more likely to suffer from HRI in the Unites States and that Latino workers bear a disproportionate burden of workplace injuries.[18,43] If we want to effectively address the health disparities present in WA, we must be able to guarantee the protection of vulnerable communities in their place of work. Incorporating reliable and complete data on race and ethnicity into occupational safety and health data systems, for example, workers compensation and the BLS SOII, will allow the detection of racial and ethnic disparities in occupational injuries and illness. Current efforts

in including these data into occupational health surveillance systems are inadequate, thus likely perpetuating occupational health disparities into the foreseeable future.[44]

Our analysis of HRI rates by detailed industry also revealed some industries which have low counts of detected HRI cases but high rates due to the small number of people working in that industry. Both employees of Convention and Visitor Bureaus and Support Services for Forestry fell into this category. Those that work in the Administration of Conservation Programs have an elevated rate of HRI with a third quarter rate of 282 cases per 100 000 FTE. These industries with a smaller absolute number of cases but high rates suggest that examining rates by industry is an important tactic to identify specific industries that could benefit from HRI prevention programs. The difference in the acceptance rate by industry sector also suggests that including rejected claims in case detection may be an important practice in analyzing workers' compensation data. As we observed in our data, claims may be denied if there is ambiguity about the association between the disease or condition and workplace exposures during the claims process. However, rejected claims occur in industries with high rates of HRI claims and likely provide additional data on workplaces where heat exposures are not being mitigated.

5 | LIMITATIONS

This descriptive study faces some limitations. First, it includes only employers insured through the WA workers' compensation State Fund, therefore excluding self-insured employers. Self-insured employers account for 30% of the workers in WA, primarily those who work at larger companies. Workers' compensation data are also insensitive. To have an HRI case entered into the database requires workers who suffered from HRI to seek medical care in addition to filing a workers' compensation claim. HRI is often not recognized by employees, employers, and medical professionals. These factors indicate that the number of HRI cases detected in this paper is likely an underrepresentation of the true number of cases among Washington workers.

We also lack the details of exposure to HRI risk factors for each individual HRI case. Acclimatization affects the susceptibility of individuals to HRI and we do not have data regarding patterns of work and heat exposure to inform whether the worker was acclimatized. We were not able to assess worker access to rest breaks and cooling, but they remain important factors that allow workers to prolong their exposure to the heat and could impact the association between HRI and ambient temperature. There are also payment systems, one example being piece rate in agriculture that can deincentivize water and rest breaks among employees. The use of PPE can also affect the temperature at which someone experiences HRI. By using PPE that traps more heat, individuals face an increased risk of HRI at lower temperatures. There are also specific medications and prior medical conditions that can contribute to an increased risk of HRI for individuals. Such medications include diuretics and other antihypertensives which can place individuals at an increased risk due to dehydration and altered cardiovascular responses to heat stress.[45] It is possible that these factors contributed to some of the HRI cases detected. Additionally, our final analysis only included the single climate variable outlined in the WA heat rule, which is ambient temperature. This meant our analysis did not consider the effect of humidity, wind, or solar radiation on HRI.

6 | CONCLUSION

The methods and data reviewed in this study can be used to improve the monitoring and prevention of HRI among workers in WA. Washington's Division of Occupational Safety and Health (DOSH), which enforces workplace safety and health rules, can utilize the case detection method for real time monitoring of HRI among workers' compensation claims. High probability HRI claims could trigger an automatic referral of the case to DOSH. Ultimately, this could facilitate a more rapid response by DOSH in the form of a site visit, especially in the third quarter when the HRI rate is the highest. By identifying the industry sectors that experience the highest rate of HRI, the DOSH outreach team can develop targeted public health campaigns to prevent HRI. The results of this descriptive study will be used to inform state-run HRI prevention campaigns and allow them to focus on industries most at risk of HRI. Our analysis of temperature data linked to detected HRI cases revealed that many HRI cases are occurring below the 89°F threshold for the WA heat rule. Our results suggest that the current heat rule threshold should be lowered and employers mandated to provide access to shade. Both of these recommendations align with current NIOSH recommendations to reduce HRI in workplaces.[20,46]

While the current threshold for Washington's heat rule may not offer complete protection of workers from HRI, Washington is still one of two states that currently have specific regulation to protect outdoor workers from HRI. There are many other states without a heat rule that experience hotter and more humid climates and have large employed populations in industry sectors that had high rates of HRI in our data. It is highly likely that these states have high rates of occupational HRI. Data from the Council of State and Territorial Epidemiologists show that Louisiana, Mississippi, Kentucky, and Tennessee had the highest rates of occupational HRI based on available emergency department data.[47] None of these states have heat rules to protect workers. Additionally, a previous study found that California and Texas had the highest number of HRI fatalities between 2014 and 2016.[16] Although the general duty clause dictates that employers have a duty to protect workers from harmful conditions, prior cases has shown that this clause is often not enough to attribute responsibility for protecting workers from HRI to the employer.[48] Multiple advocacy groups have recognized the danger that HRI poses to occupational health with the increasing effects of climate change and have been urging the U.S. Occupational Safety and Health Administration to set a specific standard to prevent HRI and hold employers accountable.[49]

We hope that the results of this descriptive study can be used to better inform the need for worker protections from HRI in other

states and at a national level. HRI will only become a more urgent public health threat with climate change. We know that it will also likely disproportionately affect vulnerable populations including those with a low socio economic status, immigrants, temporary workers, and ethnic and racial minorities. There are effective strategies to prevent occupational HRI such as training, awareness, and administrative controls like shifting work to the cooler hours earlier in the day. Climate change and HRI will continue to pose an increasing threat to everyone in our homes and our workplaces. This workplace threat is heightened among outdoor workers. However, with knowledge of trends in rates and industries most affected, we can develop effective interventions and policies to reduce HRI and protect the health and wellbeing of the Washington workforce.

ACKNOWLEDGMENTS

We thank Dr. June Spector for her thoughtful review of a draft manuscript. The study was supported by the Washington State Department of Labor and Industries. The authors report that there was no funding source for the work that resulted in the article or the preparation of the article.

CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John D Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

AUTHOR CONTRIBUTIONS

MH participated in the design of the work, analysis, and interpretation of the data, drafting the work and revising it for intellectually important content. SW participated in critically revising the work for important intellectual content and interpretation of the data for the work. AR and DA participated in the acquisition of the data for this study. CS participated in the analysis of a component of the data. DB participated in the design of the work, acquisition of the data, analysis and interpretation of the data, drafting the work and revising it for intellectually important content. He will also provide the final approval for the version to be published and agrees to be accountable for all aspects for the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

ETHICS APPROVAL AND INFORMED CONSENT

Washington State Department of Labor and Industries' employees and contractors conducted this study to develop a means to track occupational HRI and evaluate Washington State's current efforts to control heat related illness. The study was conducted by a public health authority with statutory obligations to compile statistics and data for the control of occupational injuries and illnesses which includes occupational heat related illness. The study is public health practice and is exempt from IRB review.

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REFERENCES

1. Jackson JE, Yost MG, Karr C, et al. Public health impacts of climate change in Washington State: projected mortality risks due to heat events and air pollution. *Clim Change*. 2010;102(1-2):159-186.
2. Bureau of Labor Statistics. Census of Fatal Occupational Injuries. U.S. Department of Labor. 2017.
3. Luber G, McGeehin M. Climate change and extreme heat events. *Am J Prev Med*. 2008;35(5):429-435.
4. WHO calls for urgent action to protect health from climate change–Sign the call [press release]. World Health Organization. 2015.
5. Christensen JH, Hewitson B, Busuioc A. Regional Climate Projections. In: Solomon S, Qin M, Manning M, Marquis M, Averyt K, Tignor M, Jr.Miller H, eds. *Contribution of Working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: University Press; 2007:847-940.
6. Centers for Disease Control and Prevention. Heat-related deaths among crop workers—United States, 1992–2006. *Morb Mortal Wkly Rep*. 2008;57(24):649-653.
7. Levy BS, Roelofs C. Impacts of Climate Change on Workers' Health and Safety. *Oxford Research Encyclopedias Global Public Health*. Oxford: Oxford University Press. https://oxfordre.com/publichealth/view/10.1093/acrefore/9780190632366.001.0001/acrefore-9780190632366-e-39
8. Page L, Sheppard S. *Heat Stress: The Impact of Ambient Temperature on Occupational Injuries in the US*. Williamstown, MA: Williams College Department of Economics; 2016. Department of Economics Working Papers 2016-16.
9. Spector JT, Bonauto DK, Sheppard L, et al. A case-crossover study of heat exposure and injury risk in outdoor agricultural workers. *PLOS One*. 2016;11(10):e0164498.
10. Binazzi A, Levi M, Bonafede M, et al. Evaluation of the impact of heat stress on the occurrence of occupational injuries: meta-analysis of observational studies. *Am J Ind Med*. 2019;62(3):233-243.
11. Bonauto D, Anderson R, Rauser E, Burke B. Occupational heat illness in Washington State, 1995–2005. *Am J Ind Med*. 2007;50(12):940-950.
12. Spector JT, Krenz J, Rauser E, Bonauto DK. Heat-related illness in Washington State agriculture and forestry sectors. *Am J Ind Med*. 2014;57(8):881-895.
13. Jackson LL, Rosenberg HR. Preventing heat-related illness among agricultural workers. *J Agromedicine*. 2010;15(3):200-215.
14. Arcury TA, Summers P, Talton JW, et al. Heat illness among North Carolina Latino farmworkers. *J Occup Environ Med*. 2015;57(12):1299-1304.
15. Kearney GD, Hu H, Xu X, Hall MB, Balanay JAG. Estimating the prevalence of heat-related symptoms and sun safety–related behavior among Latino farmworkers in Eastern North Carolina. *J Agromedicine*. 2016;21(1):15-23.
16. Roelofs C. Without warning: Worker deaths from heat 2014–2016. *New Solutions*. 2018;28(2):344-357.
17. Bouchama A, Knochel JP. Heat stroke. *N Engl J Med*. 2002;346(25):1978-1988.

18. Gronlund CJ. Racial and socioeconomic disparities in heat-related health effects and their mechanisms: a review. *Current Epidemiol Rep*. 2014;1(3):165-173.
19. Indoor Ventilation and Temperature in Places of Employment. Minnesota Administrative Rules 5205.0110.
20. Jacklitsch B, Williams J, Musolin K, Coca A, Kim J-H, Turner N. NIOSH. NIOSH Criteria for a Recommended Standard: Occupational Exposure to Heat and Hot Environments. By Jacklitsch B, Williams J, Musolin K, Coca A, Kim J-H, Turner N. Cincinnati, OH: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH); 2016.
21. Washington Department of Labor and Industries. Outdoor Heat Exposure; Concise explanatory statement. Tumwater, WA, 2008.
22. Outdoor Heat Exposure. Washington Administrative Code 296-62-09510. 7/5/2008.
23. Heat Illness Prevention. California Code of Regulations Vol §3395. 7/27/2006.
24. Fleischer NL, Tiesman HM, Sumitani J, et al. Public health impact of heat-related illness among migrant farmworkers. *Am J Prev Med*. 2013;44(3):199-206.
25. Gubernot DM, Anderson GB, Hunting KL. The epidemiology of occupational heat-related morbidity and mortality in the united states: a review of the literature and assessment of research needs in a changing climate. *Int J Biometeorol*. 2014;58(8):1779-1788.
26. Wuellner SE, Adams DA, Bonauto DK. Unreported workers' compensation claims to the BLS Survey of Occupational Injuries and Illnesses: Establishment factors. *Am J Ind Med*. 2016;59(4):274-289.
27. Bureau of Labor Statistics. *Occupational Injury and Illness Classification Manual*. Washington, DC: US Department of Labor; 2007.
28. Smith CK, Bonauto DK. Improving occupational health disparity research: Testing a method to estimate race and ethnicity in a working population. *Am J Ind Med*. 2018;61(8):640-648.
29. Washington State University. AgWeatherNet. Available at https://weather.wsu.edu
30. National Oceanic and Atmospheric Administration. Climate Data Online. Available at https://www.ncdc.noaa.gov/cdo-web/
31. Federal Aviation Administration. Surface Weather Observation Stations. https://www.faa.gov/air_traffic/weather/asos/?state=WA
32. NIOSH. Employed Labor Force query system. https://wwwn.cdc.gov/wisards/cps/cps_estimates.aspx. Accessed April 22, 2019.
33. Potis K. Incidence overview: Heat-related illness (HRI). Rapid Health Information Network (RHINO): Washington State Department of Health. August 12, 2019.
34. Racinais S, Périard JD, Karlsen A, Nybo L. Effect of heat and heat acclimatization on cycling time trial performance and pacing. *Med Sci Sports Exerc*. 2015;47(3):601-606.
35. Guo Y, Gasparrini A, Li S, et al. Quantifying excess deaths related to heatwaves under climate change scenarios: A multicountry time series modelling study. *PLOS Med*. 2018;15(7):e1002629.
36. Meehl GA, Tebaldi C. More intense, more frequent, and longer lasting heat waves in the 21st century. *Science*. 2004;305(5686):994-997.
37. Xiang J, Bi P, Pisaniello D, Hansen A. Health impacts of workplace heat exposure: an epidemiological review. *Ind Health*. 2014;52(2):91-101.
38. Gauer R, Meyers BK. Heat-related illnesses. *Am Fam Physician*. 2019;99(8):482-489.
39. Garzon-Villalba XP, Mbah A, Wu Y, et al. Exertional heat illness and acute injury related to ambient wet bulb globe temperature. *Am J Ind Med*. 2016;59(12):1169-1176.
40. Calkins MM, Bonauto D, Hajat A, et al. A case-crossover study of heat exposure and injury risk among outdoor construction workers in Washington State. *Scand J Work Environ Health*. 2019;45:588-599.
41. Acharya P, Boggess B, Zhang K. Assessing heat stress and health among construction workers in a changing climate: a review. *Int J Environ Res Public Health*. 2018;15(2):247.
42. McInerney M. Examining differences by ethnicity in the propensity to file for workers' compensation insurance. *The 2015 Department of Labor Scholars Program*. 2015:88.
43. Seabury SA, Terp S, Boden LI. Racial and ethnic differences in the frequency of workplace injuries and prevalence of work-related disability. *Health Aff*. 2017;36(2):266-273.
44. National Academies of Sciences, Engineering, and Medicine. *A Smarter National Surveillance System for Occupational Safety and Health in the 21st Century*. Washington, DC: National Academies Press; 2018.
45. Epstein Y. Heat intolerance: predisposing factor or residual injury? *Med Sci Sports Exerc*. 1990;22(1):29-35.
46. Tustin AW, Lamson GE, Jacklitsch BL, et al. Evaluation of occupational exposure limits for heat stress in outdoor workers—United States, 2011–2016. *Morb Mortal Wkly Rep*. 2018;67(26):733-737.
47. Occupational Health Indicators. Council of State and Territorial Epidemiologists; 2014. https://www.cste.org/page/OHIndicators. Accessed September 13, 2019.
48. Secretary of Labor v. A.H. Sturgill Roofing, Inc, (Occupational Safety And Health Review Commission, Docket No. 13-0224).
49. Tanglis M, Devine S. *Extreme Heat and Unprotected Workers: Public Citizen Petitions OSHA to Protect the Millions of Workers Who Labor in Dangerous Temperatures*. Washington, DC: Public Citizen; 2018.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Hesketh M, Wuellner S, Robinson A, Adams D, Smith C, Bonauto D. Heat related illness among workers in Washington State: A descriptive study using workers' compensation claims, 2006-2017. *Am J Ind Med*. 2020;63:300–311. https://doi.org/10.1002/ajim.23092