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RESEARCH ARTICLE

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Risk factors for occupational heat-related illness among California workers, 2000–2017

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Abstract

Background: As climate change increases global temperatures, heat-related morbidity and mortality are projected to rise. Outdoor workers and those who perform exertional tasks are particularly susceptible to heat-related illness (HRI). Using workers' compensation data, we aimed to describe rates of occupational HRI in California and identify demographic and occupational risk factors to inform prevention efforts.

Methods: We identified HRI cases during 2000–2017 in the California Workers' Compensation Information System (WCIS) using *International Classification of Diseases* Ninth and Tenth Revision codes, WCIS nature and cause of injury codes, and HRI keywords. We assigned industry and occupation codes using the NIOSH Industry and Occupation Computerized Coding System (NIOCCS). We calculated HRI rates by sex, age group, year, county, industry, and occupation, and estimated confidence intervals using generalized linear models.

Results: We identified 15,996 HRI cases during 2000–2017 (6.0 cases/100,000 workers). Workers aged 16–24 years had the highest HRI rate (7.6) among age groups, and men (8.1) had a higher rate than women (3.5). Industry sectors with the highest HRI rates were Agriculture, Farming, Fishing, and Forestry (38.6), and Public Administration (35.3). Occupational groups with the highest HRI rates were Protective Services (56.6) and Farming, Fishing, and Forestry (36.6). Firefighters had the highest HRI rate (389.6) among individual occupations.

Conclusions: Workers in certain demographic and occupational groups are particularly susceptible to HRI. Additional prevention efforts, including outreach and enforcement targeting high-risk groups, are needed to reduce occupational HRI. Workers' compensation data can provide timely information about temporal trends and risk factors for HRI.

KEYWORDS

climate change, heat stress, heat-related illness, occupational exposures, workers' compensation

1 | INTRODUCTION

Exposure to high temperatures can cause a range of heat-related illnesses, from mild heat stress-induced symptoms to life-threatening heat stroke, and can cause or exacerbate many other medical conditions. The decade from 2010 to 2019 was the hottest on record since global temperature recording began in 1880.[1] In recent decades, higher temperatures and extreme heat events have been repeatedly associated with increases in mortality.[2] As climate change continues to increase average daily temperatures and the frequency and intensity of extreme heat events, heat-related morbidity and mortality are projected to rise.[2,3]

Workers who perform exertional tasks or work in non-climate-controlled environments are particularly vulnerable to heat-related illness (HRI). These workers typically have little control over their work environments and may have limited recourse or ability to adapt when faced with extreme heat conditions in the workplace.[4] In 2018, the Bureau of Labor Statistics (BLS) estimated that 49 workers in the United States died due to environmental heat exposure, and 3130 experienced nonfatal heat-related injuries or illnesses.[5,6] Prior studies have highlighted an increased risk of occupational HRI in certain industries and occupations, such as the military, agriculture, and construction.[7–9]

In the United States, the federal Occupational Safety and Health Administration (OSHA) enacts and enforces standards to protect workers from workplace health hazards. In addition, 22 states, including California, have the authority to enact and enforce their own OSHA standards for public and private sector employees. Although the National Institute for Occupational Safety and Health (NIOSH) has developed criteria for a possible occupational heat standard,[10] there is no federal OSHA standard specifically designed to prevent HRI and protect workers in hot environments. In 2005, in response to a series of farmworker deaths from HRI, California became the first state to enact an occupational HRI prevention standard for outdoor workers, requiring employers to provide employees with training about HRI and access to water, shade, and rest.[11] In 2020, California remains one of only three states with an occupational HRI regulation.[12–14]

Despite worker susceptibility to HRI and increasing risks due to climate change, there is limited public health surveillance of occupational HRI in the United States.[15] The primary source of information available on occupational HRI comes from the BLS Survey of Occupational Injuries and Illnesses (SOII), results of which are used to estimate occupational illnesses and injuries. Studies have demonstrated that these results, which are based on self-report from a small sample of employers nationwide, underestimate the true number of occupational illnesses and injuries.[16–18] Workers' compensation data systems, which catalog worker claims for occupational illnesses and injuries, can provide an alternative source of information. Workers' compensation claims have been used in some prior studies of occupational HRI,[14,19] but are not used routinely to estimate the burden of occupational HRI.

Although California is one of only three states with an occupational HRI standard, no published studies have attempted to quantify the burden of HRI in California workers or determine which workers may be at particularly high risk. We therefore sought to describe rates of occupational HRI in California from 2000 to 2017 using statewide workers' compensation data and to compare these rates with existing estimates. We also sought to identify demographic groups, geographic locations, industries, and occupations with higher rates of HRI to help inform prevention efforts.

2 | MATERIALS AND METHODS

2.1 | HRI case identification

Workers who experienced HRI were identified through the California Workers' Compensation Information System (WCIS), an electronic database managed by the California Department of Industrial Relations. In California, nearly all employees are required to be covered by workers' compensation[1]; workers' compensation claims are initiated by an employer or health care provider report of workplace illness or injury. Since 2000, California has required workers' compensation claims administrators to report electronically to WCIS any workers' compensation claim resulting in more than 1 day of lost work time or requiring treatment beyond first aid. Submission of associated medical billing data has been required since 2006. WCIS includes both accepted and rejected claims. Extract criteria to identify HRI claims in WCIS were developed through an iterative process by a team of occupational epidemiologists and physicians. Claims were considered HRI cases if they included specific WCIS heat-related nature or cause of injury codes (e.g., cause of injury = temperature extremes), if they contained certain HRI keywords in the injury description (e.g., "heat stroke"), or if their associated billing data contained an *International Classification of Diseases* (ICD) Ninth or Tenth revision code indicating heat illness (see Appendix for complete criteria). All claims with date of injury from January 1, 2000–December 31, 2017, meeting these criteria were extracted from WCIS in January 2018. Initial review of these claims found that some claims identified from ICD criteria alone were not in fact heat-related. Claims meeting only ICD criteria were therefore manually reviewed, and only those deemed by a reviewer to be heat-related based on the injury description were included as HRI cases.

HRI cases were categorized by sex and age group, month and year of injury, county of injury, time from hire date to injury, industry, and occupation. The county of injury was determined using the zip code of injury; claims where the location of injury was outside California were excluded. Claims involving workers aged below 16 years and those involving inmate workers were excluded to align with employment denominator data used in rate calculations.

[1]Most employees in California are covered by workers' compensation; certain non-employees, such as voluntary, non-compensated workers, and owners of corporations are excluded: https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=LAB&sectionNum=3352. Employees covered under separate federal programs (including federal employees and longshoremen) are also excluded.

Employment denominators used in rate calculations for all variables except county were obtained from the NIOSH Employed Labor Force tool, which estimates total numbers of workers based on the U.S. Census Current Population Survey and includes all non-institutionalized civilian workers aged 16 and older.[20] Because of a significant change in census industry and occupation coding schemes in 2002, employment denominators from 2000 to 2001 were extrapolated from 2002 to 2017 data. Employment denominators by county were obtained from the California Employment Development Department.[21]

HRI cases identified through workers' compensation data were compared with BLS SOII estimates of HRI among California workers, which were available from 2009 to 2017, and to number of claims reported to WCIS from all causes.

2.2 | Industry and occupation coding

In WCIS, employer industry is classified for most claims by individual claims adjusters who report claims to WCIS, using the North American Industrial Classification System (NAICS).[2] Cases missing industry code were classified by listed employer; for employers with more than one claim, cases were reviewed by the study team and NAICS codes were assigned based on information about the employer available publicly via an Internet search. To align with the employment denominators used in this analysis, NAICS codes were cross-walked to 2002 census industry codes using NIOSH Industry and Occupation Computerized Coding System (NIOCCS) software.[22] Industry codes and free-text occupation descriptions from WCIS were then inputted into NIOCCS, which automatically generated census occupation codes for most cases. For cases that were not successfully auto-coded by NIOCCS, industry-occupation description pairs with more than 10 claims were reviewed and manually assigned an occupation code by a member of the study team if sufficiently specific information was available to do so. Cases were categorized by individual industry and occupation as well as by broader industrial sector and occupational group.[3]

2.3 | Rate and rate ratio calculations

HRI rates were calculated for all variables for which employment denominator data were available, including sex, age group, county of injury, industry, and occupation. Employment denominators were not available for the month of injury or time from hire date to injury; rates were therefore not calculated for these variables. Rates were calculated by dividing the total number of HRI cases over the study period by the total number of workers and multiplying by 100,000 to yield rates per 100,000 workers. Rates were also calculated by individual year and by 6-year intervals. Confidence intervals were estimated using a generalized linear model with a Poisson distribution to account for uncertainty in numbers of HRI cases and total numbers of workers. Given the change in WCIS reporting requirements and lack of availability of ICD codes before 2006, a sensitivity analysis examining rates over time was also conducted excluding cases identified only by ICD codes. All analyses were performed using SAS software version 9.4 (SAS Institute).

The prevention index is a combined ranking of the number of cases and HRI rates that can be used to identify high-priority industries and occupations for intervention, as previously described elsewhere.[23] A prevention index was calculated as the average of the ranks for the number of cases and for the HRI rate for each individual industry and occupation ((Count rank + Rate rank)/2).

This study is public health practice, not research, and is exempt from IRB review.

3 | RESULTS

3.1 | HRI cases

There were 13,037,797 unique WCIS claims from 2000 to 2017. Using the extract criteria detailed in the Appendix, 18,589 of these claims were initially identified as heat-related. After excluding claims that did not meet inclusion criteria (Figure 1), 15,996 HRI cases remained, representing a rate of 6.0 HRI cases/100,000 workers during 2000–2017.

3.2 | Demographic and geographic characteristics

A total of 11,585 HRI cases (72.4%) occurred in men, representing a rate of 8.1 cases/100,000 workers; rates among men were 2.3 times higher than among women (95% confidence interval [CI]: 2.3–2.4; Table 1). HRI rates were highest among younger workers, with a rate of 7.6/100,000 among workers aged 16–24 years, which was 1.4 times higher than among workers aged 35–44 years (95% CI: 1.3–1.4; Table 1).

Ninety-six percent of cases included a valid zip code of injury. The highest HRI rates occurred in southern California counties, including Imperial (36.6), San Diego (32.7), and Los Angeles (31.8) (Figure 2).

3.3 | Temporal characteristics and trends

The number of annual HRI cases and HRI rates increased over time; 2017 had the highest number of HRI cases (1616) and HRI rates (10.1 cases/100,000 workers; Figure 3A). Analysis of HRI rates by 6-year period also demonstrated an increase over time (Table 1); the

[2]NAICS codes are assigned by individual claims adjusters before reporting to WCIS. Some older claims were classified in WCIS using Standard Industrial Classification (SIC) codes; these were cross-walked to NAICS codes using standard SIC-NAICS crosswalk codes available at https://www.naics.com/naics-to-sic-sic-to-naics-crosswalks/.

[3]The Census classification system includes 270 individual industries categorized into 20 broader industry sectors, and 509 individual occupations categorized into 23 major occupational groups. Additional detail available at https://www.census.gov/programs-surveys/cps/technical-documentation/methodology/industry-and-occupation-classification.html

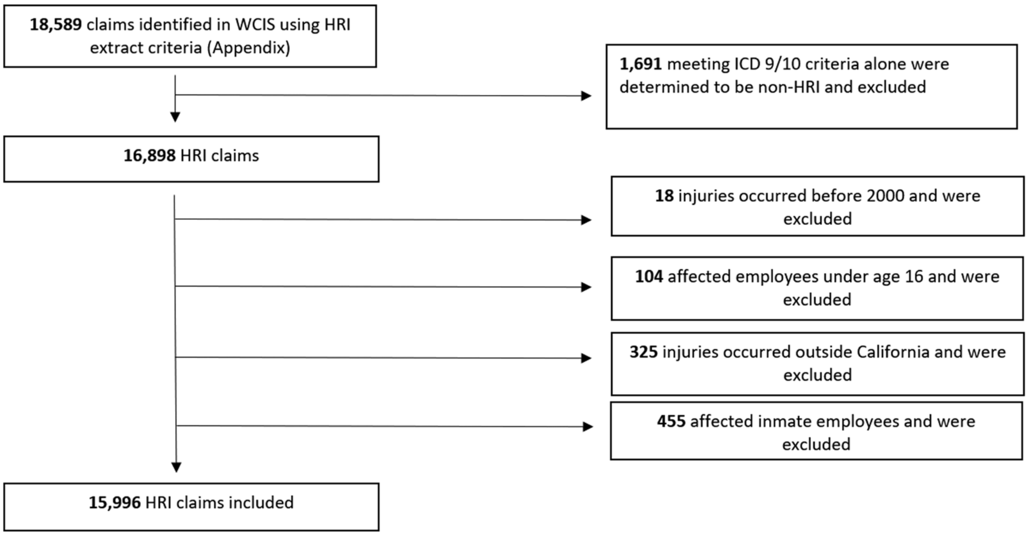

FIGURE 1 California Workers' Compensation Information System (WCIS) claims identified as heat-related illness (HRI), 2000–2017

HRI rate from 2012 to 2017 was 2.0 (95% CI: 1.9–2.1) times greater than from 2000 to 2005. Though the number of HRI cases in WCIS increased from 2000 to 2017, the number of all-cause WCIS claims initially decreased then remained relatively stable (Figure 3B). The number of HRI cases estimated from BLS SOII data increased from 2009 to 2017, but the number of HRI cases identified from WCIS was three to six times higher annually than the number estimated from BLS SOII (Figure 3C). A sensitivity analysis excluding the 1225 cases identified by ICD code alone revealed similar trends.

TABLE 1 Number of cases and rates of occupational heat-related illness by demographic group and time period, California, 2000–2017[a]

Characteristic	Number of cases (%)	Rate (95% CI)[b]	Rate ratio (95% CI)
Age (years)			
16–24	2950 (18.4)	7.6 (7.3–7.9)	1.4 (1.3–1.4)
25–34	4421 (27.6)	6.8 (6.6–7.0)	1.2 (1.2–1.3)
35–44	3546 (22.2)	5.6 (5.4–5.8)	Referent
45–54	3139 (19.6)	5.5 (5.3–5.7)	1.0 (0.9–1.0)
55–64	1587 (9.9)	4.8 (4.6–5.1)	0.9 (0.8–0.9)
≥65	353 (2.2)	4.3 (3.9–4.8)	0.8 (0.7–0.9)
Sex			
Male	11,585 (72.4)	8.1 (8.0–8.3)	2.3 (2.3–2.4)
Female	4318 (27.0)	3.5 (3.4–3.6)	Referent
Time period			
2000–2005	3309 (20.7)	3.8 (3.7–3.9)	Referent
2006–2011	5676 (35.5)	6.6 (6.3–6.7)	1.7 (1.7–1.8)
2012–2017	7011 (43.8)	7.6 (7.4–7.8)	2.0 (1.9–2.1)

Abbreviation: 95% CI, 95% confidence interval.

[a]Data source: California Workers' Compensation Information System.

[b]Heat-related illness cases per 100,000 workers.

Most HRI cases occurred in summer months (Figure 4); July had the highest number of cases (4199 cases; 26.3%), followed by August (3161 cases; 19.8%) and June (2915 cases; 18.2%). A total of 1427 HRI cases (8.9%) occurred within 2 weeks of the reported employee hire date; 410 (2.6%) occurred on the worker's first day of employment.

3.4 | Industry and occupation

After WCIS data extraction and supplemental manual coding, industry codes were available for 13,835 HRI cases (86%).

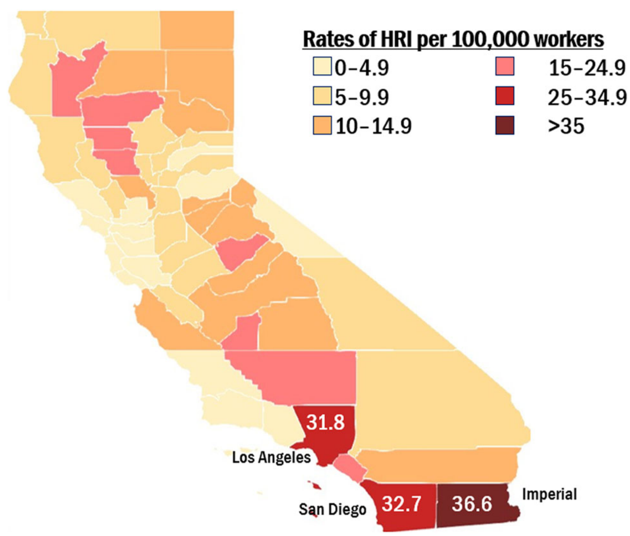

FIGURE 2 Rates of heat-related illness (HRI) by county, California, 2000–2017. *Data source: California Workers' Compensation Information System. *Counties with rates of HRI > 25 per 100,000 workers are labeled [Color figure can be viewed at wileyonlinelibrary.com]

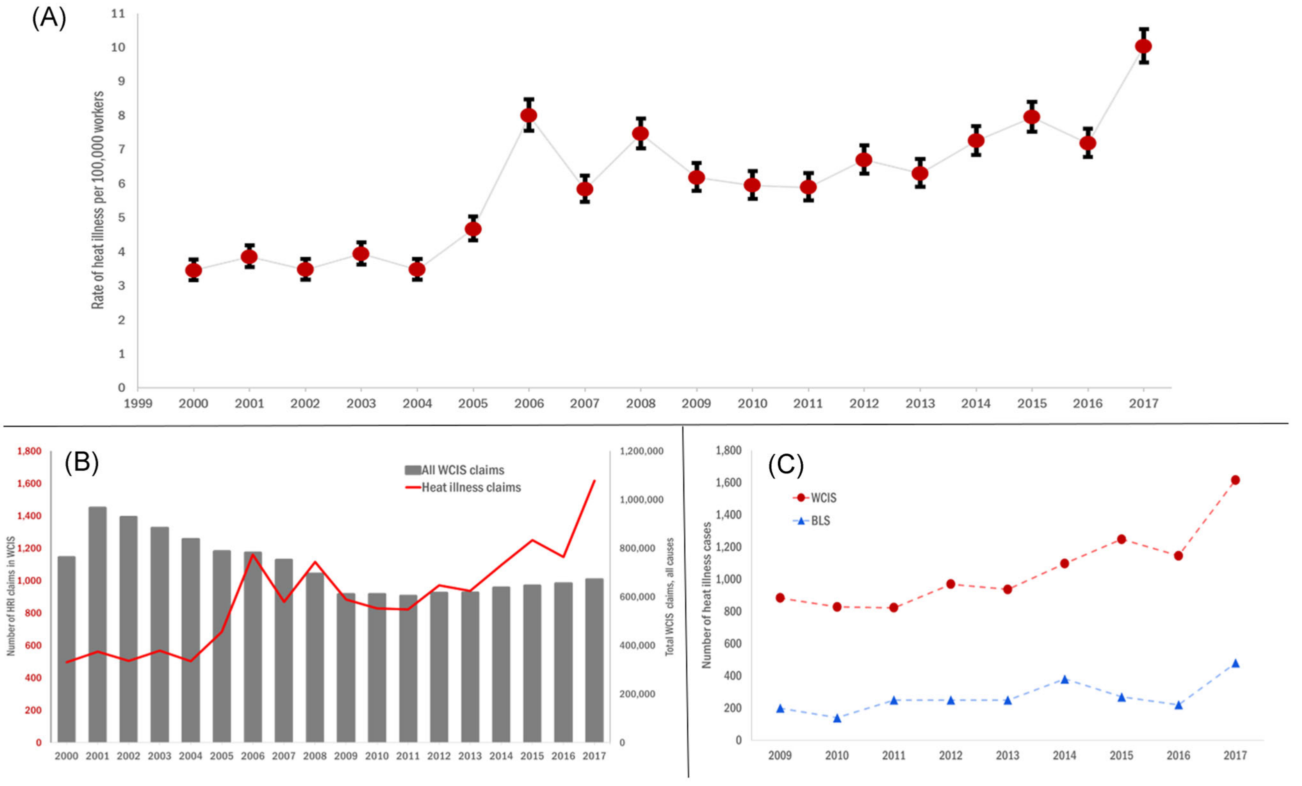

FIGURE 3 Trends in occupational heat-related illness (HRI) over time, by data source and year of injury, California, 2000–2017. (A) Rates of HRI calculated using Workers' Compensation Information System (WCIS) data. Points are rate estimates and bars are 95% confidence intervals. (B) Number of HRI claims compared to the total number of WCIS claims. (C) Number of HRI cases identified using WCIS data compared to estimates from Bureau of Labor Statistics (BLS) Survey of Occupational Illness and Injury (SOII) data, 2009–2017 (BLS data not available 2000–2008) [Color figure can be viewed at wileyonlinelibrary.com]

The Agriculture, Forestry, Fishing, and Hunting industry sector had the highest HRI rate (38.6 cases/100,000 workers), followed by Public Administration, which includes certain public sector and public safety establishments (35.3/100,000; Table 2). Within the Agriculture, Forestry, Fishing, and Hunting sector, the individual industry with the highest number of cases were Crop Production (1335 cases; 41.1/100,000), and the individual industry with the highest HRI rate was Support Activities for Agriculture and Forestry, which includes establishments providing processing and other services for agriculture and forestry production (449 cases; 65.1/100,000). Among all individual industries, rates were also elevated for Natural Gas Distribution (123 cases; 66.1/100,000) and Employment Services (506 cases; 24.9/100,000), a group that includes temporary employment agencies. The individual industry with the lowest prevention index (i.e., highest priority for intervention) was Justice, Public Order, and Safety Activities, which includes fire and police protection establishments (Table 3).

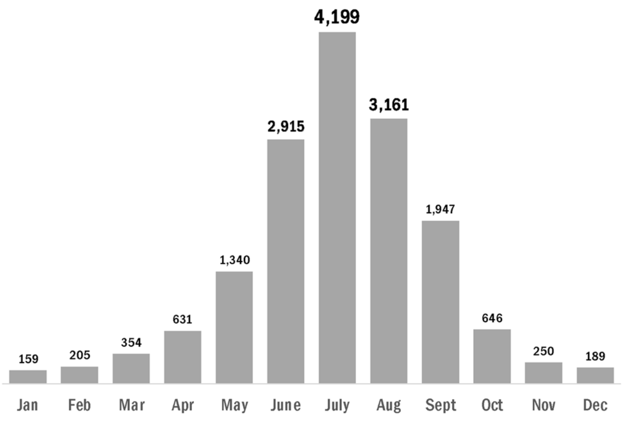

FIGURE 4 Number of cases of occupational heat-related illness by month of injury, California, 2000–2017

Occupation was successfully coded for 11,875 cases (74%). The occupational group with both the highest number of cases and the highest HRI rate was Protective Service occupations, which includes occupations such as police and firefighters, with 3380 cases and a rate of 56.7/100,000 workers (Table 4). Among individual occupations, rates and case counts were highest among firefighters, with 1796 cases (390.7/100,000). Firefighters also had the lowest prevention index (i.e., highest priority for intervention; Table 3). Other individual occupations with high HRI rates included conservation scientists and foresters (298.9/100,000), police officers (51.3/100,000), lifeguards and other protective service workers (49.6/100,000), and miscellaneous agricultural workers (41.5/100,000).

4 | DISCUSSION

HRI is a preventable occupational illness, with well-established strategies to protect workers. These include allowing workers to acclimatize to heat; providing adequate water, shade, and rest breaks; and training workers and employers about heat illness recognition and prevention, all of which are outlined in existing guidelines and regulations.[10,11,24] Nevertheless, this study demonstrates that occupational HRI continues to increase, even in California, one of only three U.S. states with an occupational standard to prevent HRI. In addition, the number of HRI claims identified in this study using workers' compensation data was consistently higher than the number of cases estimated by BLS SOII, suggesting that existing sources of data may underestimate HRI incidence and that workers' compensation data may provide a valuable additional source of information.

Younger workers and male workers appear to be at particularly high risk of HRI, consistent with prior studies of occupational HRI.[14,19,25] Some studies of heat illness in the general population have also found men to be at higher risk.[26] This difference may be due in part to increased physiologic susceptibility; in the occupational setting, men may also be more likely to work in industries or occupations at higher risk of HRI or to perform work with higher metabolic demands. The higher rates of HRI identified among younger workers in our study, however, are in contrast to the general population, where older adults are often found to be at the highest risk of HRI.[27,28] This difference may be explained in part by higher numbers of younger workers in industries or occupations at higher risk of HRI, or lack of work experience among younger workers.

Lack of work experience and acclimatization are well-established risk factors for HRI; this study found that 9% of HRI cases occurred within 2 weeks of hire. Prior studies of occupational HRI in the military and among forestry workers have also identified higher rates of HRI among recently hired workers.[29,30] In addition, a study of federal OSHA citations due to heat illness identified “failure to support acclimatization” as a leading risk factor for heat illness and heat-related death.[31] These findings highlight the importance of following established guidelines for allowing new workers to acclimatize to heat and of implementing procedures to closely monitor workers for signs of heat-related illness soon after hiring and during high-heat events.

This study also identified specific industries and occupations with higher rates of HRI among workers, including agriculture and public safety. Similar industries and occupations have been identified as high-risk in prior studies of occupational HRI. In an analysis of workers in Washington State that also used workers' compensation data, construction, agriculture, and public administration were identified as the industrial sectors with the highest HRI rates, though estimated rates for agriculture and public administration (13 and 10 cases per 100,000 workers, respectively) were lower than those identified here (38 and 35 per 100,000 workers).[14] A study of occupational heat-related mortality in the United States also identified the agriculture and construction sectors as having the highest rates of heat-related mortality.[7] There are many factors that may contribute to higher rates of HRI in these industries and occupations, such as higher metabolic demands of work, protective gear

TABLE 2 Number of cases and rate of occupational heat-related illness by industry sector, California, 2000–2017[a]

Industry group[b]	Number of cases (%)	Rate (95% CI)[c]
Agriculture, forestry, fishing, and hunting	1846 (13.3)	38.6 (26.9–40.4)
Public administration	4784 (34.6)	35.3 (34.3–36.3)
Mining	108 (0.8)	21.3 (17.6–25.7)
Utilities	267 (1.9)	11.4 (10.1–12.8)
Administrative and support and waste management	1052 (7.6)	8.8 (8.3–9.3)
Construction	1114 (8.1)	6.9 (6.5–7.3)
Management of companies and enterprises	14 (0.1)	5.9 (3.5–10.0)
Arts, entertainment, and recreation	329 (2.4)	5.5 (4.9–6.1)
Transportation and warehousing	533 (3.9)	4.9 (4.5–5.3)
Information	276 (2.0)	3.4 (3.0–3.8)
Wholesale trade	249 (1.8)	3.1 (2.8–3.6)
Manufacturing	763 (5.5)	2.6 (2.4–2.8)
Retail trade	634 (4.6)	2.1 (2.0–2.3)
Accommodation and food services	401 (2.9)	2.1 (1.9–2.3)
Professional, scientific, and technical services	374 (2.7)	2.0 (1.8–2.2)
Real estate and rental and leasing	108 (0.8)	2.0 (1.7–2.4)
Educational services	498 (3.6)	2.0 (1.9–2.2)
Other services (except public administration)	155 (1.1)	1.2 (1.0–1.4)
Health care and social assistance	262 (1.9)	0.8 (0.7–0.9)
Finance and insurance	58 (0.4)	0.5 (0.4–0.6)

Abbreviation: 95% CI, 95% confidence interval.

[a]Data source: California Workers' Compensation Information System.

[b]Industry code was missing for 2161 cases (13.5%). Percent of cases for each group is calculated among the 13,835 cases with industry data available.

[c]Heat-related illness claims per 100,000 workers.

TABLE 3 Individual industries and occupations with lowest prevention indices[a] for heat-related illness, California, 2000–2017[b]

	Number of cases	Count rank	Rate (95% CI)	Rate rank	Prevention index
Industry					
Justice, public order, and safety activities	3459	1	61.9 (59.8–64.0)	4	2.5
Crop production	1335	2	41.1 (39.0–43.4)	5	3.5
Support activities for agriculture and forestry	449	6	65.1 (59.4–71.5)	3	4.5
Employment services	506	5	24.9 (22.9–27.2)	10	7.5
Natural gas distribution	123	18	66.1 (55.4–78.9)	2	10
Occupation					
Firefighters	1796	1	390.6 (373.0–409.2)	1	1
First-line supervisors of firefighting and prevention workers	266	8	191.2 (169.5–215.6)	3	5.5
Police officers	744	3	51.3 (47.8–55.1)	9	6
Miscellaneous agricultural workers	1353	2	41.5 (39.3–43.8)	15	8.5
Conservation scientists and foresters	96	22	298.9 (244.7–365.1)	2	12

[a]Prevention index = (Count rank + Rate rank)/2. Lower prevention indices indicate higher priority industries and occupations for intervention.[23]
[b]Data source: California Workers' Compensation Information System.

requirements, and ways in which work is structured, including piece-rate payments and productivity incentives. Ongoing prevention efforts are needed in these high-risk industries and occupations; such efforts should focus on identifying and addressing risk factors specific to each high-risk group.

In California, certain industries are required to take additional measures to protect workers from HRI under the occupational heat illness prevention standard. Agriculture, construction, landscaping, oil and gas extraction, and transportation and delivery are required to implement specific "high-heat" procedures,[11] and outreach and education campaigns by Cal/OSHA have focused on agriculture as a particularly high-risk sector.[32] In general, the industries targeted under the California standard include many of those identified by this study as higher risk. One notable exception, however, is public safety occupations, including firefighters and police officers. We found that firefighters had the highest HRI rate of any occupation; they also had the lowest prevention index, indicating high priority for intervention. Risk of HRI in this group, in particular among wildland firefighters, is likely to continue to increase as wildfire seasons become longer and more severe.[33] Although firefighting presents significant challenges for heat illness prevention, given the high heat exposure and exertion involved and heavy personal protective equipment required,[34] these findings suggest that this group merits additional attention and intervention.

Another industry of concern identified by this study is the employment services industry, which includes employees hired by temporary staffing agencies, who may be working in a variety of industries and occupations. Although temporary employment has been associated with adverse occupational health and safety outcomes in a variety of settings,[35] to our knowledge it has not previously been highlighted as a risk factor for occupational HRI. Adequate HRI training and acclimatization may be more challenging to enact for temporary employees, particularly if the responsibility is not clarified between the staffing agency and the host employer. Under the California heat standard and other federal OSHA standards, employers are responsible for ensuring the safety of both permanent and temporary employees; this industry's high rate of HRI and high-priority prevention index suggests that it may present a high-yield opportunity for intervention.

Despite the passage of California's occupational HRI standard in 2005 and subsequent revisions and associated expansion of education and outreach efforts, we observed increasing HRI rates over time. Interpreting these temporal changes, however, is challenging for several reasons. First, although the passage of a heat illness standard and associated outreach might be expected to decrease rates of HRI, they also likely led to increased awareness among workers and employers, which may have resulted in increases in reporting. In addition, reporting requirements to WCIS have changed over time. Although electronic reporting became mandatory in 2000, there may have been a lag before claims administrators became fully compliant. Providing medical billing data, including ICD codes, was not required until 2006; because our extract criteria included ICD codes, we might, therefore, expect to see an increase in the number of HRI claims identified starting in 2006, though a sensitivity analysis excluding claims identified only by ICD code revealed similar trends in HRI rates throughout the study period. Despite these limitations, however, the increase in HRI claims over time contrasts with the trend in overall WCIS claims, which have remained stable or decreased over the same time period.

The findings reported here are subject to several additional limitations. Although numbers of HRI cases identified in our study are higher than those from other sources, such as BLS SOII, they are still likely to be underestimates; illnesses and injuries where heat was a contributing or principal factor are not always recognized as heat-related, and occupational illnesses and injuries are not always reported to

TABLE 4 Number of cases and rate of occupational heat-related illness by major occupational group, California, 2000-2017*

Occupational group[a]	Number of cases (%)	Rate (95% CI)[b]
Protective services	3380 (28.4)	56.7 (54.9-58.7)
Farming, fishing, and forestry	1398 (11.8)	35.9 (34.1-37.9)
Material moving	859 (7.2)	12.3 (11.5-13.1)
Construction and extraction	1188 (10.0)	8.9 (8.4-9.4)
Building and grounds cleaning and maintenance	660 (5.5)	6.0 (5.6-6.5)
Installation, maintenance, and repair	468 (3.9)	5.5 (5.0-6.0)
Transportation and material moving	458 (3.8)	5.3 (4.8-5.8)
Life, physical, and social sciences	157 (1.3)	5.0 (4.2-5.8)
Production	689 (5.8)	4.5 (4.2-4.9)
Arts, design, entertainment, sports, and media	140 (1.8)	2.5 (2.2-3.0)
Food preparation and serving	308 (2.6)	2.1 (1.8-2.3)
Architecture and engineering	129 (1.1)	2.0 (1.7-2.4)
Office and administrative support	653 (5.5)	1.8 (1.6-1.9)
Community and social services	74 (0.6)	1.7 (1.4-2.2)
Personal care and services	137 (1.2)	1.4 (1.2-1.6)
Management	361 (3.1)	1.4 (1.3-1.6)
Sales and sales-related	318 (2.7)	1.1 (1.0-1.3)
Health care practitioners and technicians	135 (1.1)	1.1 (0.9-1.3)
Health care support	52 (4.4)	1.0 (0.8-1.3)
Business and financial	98 (0.8)	0.8 (0.7-1.0)
Education, training, and library	127 (1.1)	0.8 (0.7-1.0)
Legal	11 (0.1)	0.4 (0.2-0.6)
Computer and mathematical science	16 (0.1)	0.2 (0.1-0.3)

Note: *Unable to code 4121 cases (24.8%) for occupation. Percentages are calculated among the 11,875 cases with occupation data available.
[a]Data source: California Workers' Compensation Information System.
[b]Heat-related illness claims per 100,000 workers.

workers' compensation. Rates of reporting may also differ by industry and occupation; certain groups of workers, such as those unaware of workers' compensation eligibility, or those who may be particularly vulnerable to employer reprisal, may be less likely to report their injuries and file workers' compensation claims, leading to differential underestimation of rates of HRI among industries and occupations. Industry and occupation codes were not available for all claims and were subject to misclassification based on inconsistencies among individual claims adjusters who assign industry codes when claims are filed. In addition, we were unable to examine other potential risk factors for heat-related illnesses, such as race/ethnicity and medical comorbidities,[27] which are not included in WCIS data. Finally, we did not examine the relationship between temperature and heat illness; numerous other studies have documented increases in rates of heat illness with increasing temperatures, in both occupational and nonoccupational populations.[2,14]

Despite these limitations, however, this study demonstrates the persistence of HRI among workers, even in states such as California with more stringent regulations, and highlights the ongoing need for additional prevention efforts. As global temperatures continue to rise in the coming decades, it is likely that certain groups of workers will continue to be disproportionately affected; increasing efforts will be needed to protect workers from heat-related illness.[36,37] To inform public health interventions and enforcement efforts, reliable data on risk factors for HRI and rates of HRI over time are needed.

This study demonstrates that workers' compensation data can provide a valuable source of information about occupational HRI. In addition to capturing higher rates of occupational HRI than existing data sources, the use of readily available workers' compensation data allowed for documentation of temporal trends and identification of demographic and occupational risk factors for HRI. Counts and rates of HRI estimated from workers' compensation data were also used to calculate prevention indices, which can help target prevention efforts. In the face of a changing climate, enhanced HRI surveillance and prevention efforts will be increasingly needed to monitor trends in HRI over time and protect vulnerable workers from these preventable occupational illnesses.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

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

AUTHOR CONTRIBUTIONS

Amy Heinzerling, Rebecca L. Laws, and Robert Harrison participated in the design of the work. Amy Heinzerling, Rebecca L. Laws, and Matt Frederick participated in the acquisition and analysis of the data. Amy Heinzerling drafted the work; Amy Heinzerling, Rebecca L. Laws, Matt Frederick, Rebecca Jackson, Gayle Windham, Barbara Materna, and Robert Harrison participated in the interpretation of the data and revising of the work for intellectually important content and provided final approval of the work. Amy Heinzerling agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the California Division of Workers' Compensation. Restrictions apply to the availability of these data, which were used under license for this study.

DISCLAIMER

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the California Department of Public Health.

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APPENDIX A: CASE DEFINITION FOR OCCUPATIONAL HEAT-RELATED ILLNESS IDENTIFIED FROM CALIFORNIA WORKERS' COMPENSATION INFORMATION SYSTEM (WCIS) CLAIMS, CALIFORNIA, 2000–2017

WCIS claims were considered HRI cases if they met at least one of the following criteria:

1. Nature of Injury Code = 32 (Heat Prostration)
2. Nature of Injury Code = 53 (Syncope) **and** Cause of Injury Code = 03 (Temperature Extremes) **and** Injury Description keywords! = "Cold"
3. Nature of Injury Code = 53 (Syncope) **and** Injury Description keywords = "Heat"
4. Cause of Injury Code = 03 (Temperature Extremes) **and** Injury Description keywords = "Dizz*"
5. Injury Description keywords = "Heat Stroke" **or** "Heat Exhau*" **or** "Heat Prost*"
6. ICD9 code = 992.0-992.9 **or** E900.0-E900.9*
7. ICD10 code = T67.0-T67.9 **or** X30 **or** W92*

*To improve specificity, claims meeting only criteria 6 or 7 were manually reviewed and included only if they were determined to be heat-related. This determination was made based on the description of the injury in the free-text Injury Description field; claims where the description was consistent with a heat-related illness (e.g., an episode of syncope in an employee working outdoors) were included, while claims where the description was more consistent with an alternate type of injury (e.g., a mechanical fall, or an injury caused by cold rather than heat exposure) were excluded.