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Heat-Related Illness in Washington State Agriculture and Forestry Sectors

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Abstract

Background—We sought to describe heat-related illness (HRI) in agriculture and forestry workers in Washington State.

Methods—Demographic and clinical Washington State Fund workers' compensation agriculture and forestry HRI claims data (1995–2009) and Washington Agriculture Heat Rule citations (2009–2012) were accessed and described. Maximum daily temperature (T_{max}) and Heat Index (HI_{max}) were estimated by claim date and location using AgWeatherNet's weather station network.

Results—There were 84 Washington State Fund agriculture and forestry HRI claims and 60 Heat Rule citations during the study period. HRI claims and citations were most common in crop production and support subsectors. The mean T_{max} (HI_{max}) was 95°F (99°F) for outdoor HRI claims. Potential HRI risk factors and HRI-related injuries were documented for some claims.

Conclusions—Agriculture and forestry HRI cases are characterized by potential work-related, environmental, and personal risk factors. Further work is needed to elucidate the relationship between heat exposure and occupational injuries.

Keywords

Heat-related illness; heat exhaustion; heat stroke; agricultural workers; farm workers; forestry workers; workers' compensation

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INTRODUCTION

Heat-related illness (HRI) consists of a spectrum of disorders ranging from heat rash to heat stroke, which can be fatal [Luber et al., 2006; WHO, 2009]. Unlike classical heat stroke, which occurs more commonly in the elderly, very young, and those with chronic medical conditions, exertional HRIs such as heat cramps, heat syncope (fainting), heat exhaustion, and heat stroke can occur in young, otherwise healthy individuals with high metabolic output rates from increased workloads, particularly when working in hot and humid environments.

Between 2003 and 2008, the United States (US) Agriculture, Forestry, and Fishing sector had the highest mean heat fatality rate, compared to all industries (approximately 0.3 deaths/100,000 full-time workers, compared to 0.02 for all industries) [BLS, 2011; Jackson and Rosenberg, 2010]. The majority of fatalities occurred in the crop production and support subsectors. Studies using US workers' compensation claims data have identified a high burden of non-fatal HRI in the Agriculture, Forestry, and Fishing sector despite probable substantial under-reporting [Bonauto et al., 2007].

Climate change threatens to increase the risk of HRI in outdoor workers over time. Extreme heat is associated with heat-related deaths, and the frequency and intensity of heat waves are projected to increase locally and globally [Jackson et al., 2009; Patz et al., 2005]. These findings indicate that the identification of risk factors for HRI in workers, with the overall aim of HRI prevention, is timely and of public health significance.

Although classical heat stroke and exertional HRIs in military personnel and athletes have been studied extensively, less is known about exertional HRIs in certain vulnerable working populations, including agriculture, forestry, and fishing workers [Anthony et al., 2008; Culp et al., 2011; Hansen and Donohoe, 2003; Mirabelli et al., 2010]. In 2008, Washington State adopted workplace safety standards intended to address outdoor heat exposure and prevent HRI (Washington Administrative Code 296-307-097) [WA Administrative Code, 2009]. A systematic description of Washington Heat Rule violations in agriculture, forestry, and fishing workers has to our knowledge not yet been published.

This study was performed as an initial stage in a larger US Centers for Disease Control and Prevention/National Institute for Occupational Safety and Health–funded study aimed at identifying risk factors for HRI in agricultural workers. The objective of this study was to describe demographic, work-related, environmental, temporal, geographic, clinical, and cost characteristics of HRI agriculture, forestry, and fishing workers' compensation claims in Washington State and to characterize violations of the Washington Heat Rule in the Agriculture, Forestry, and Fishing sector.

MATERIALS AND METHODS

Workers' Compensation Claims

In Washington State, employers (with several exceptions, including the self-employed, federal government, those covered under other workers' compensation systems, and

household employers with one employee) are required to obtain workers' compensation insurance through the Washington State Department of Labor & Industry (L&I) industrial insurance system unless they are able to self-insure [RCW, 2005]. L&I's State Fund covers approximately two-thirds of workers in Washington State.

Although we did not specifically exclude fishing industry workers' compensation claims from our searches for HRI State Fund claims in the Agriculture, Forestry, and Fishing sector, maritime workers are not typically covered under the State Fund. Seamen injured in the course of service to their vessels must seek legal remedy by proving employer negligence under the Merchant Marine Act of 1920, more commonly referred to as the 'Jones Act.' In addition, the federal Longshore and Harbor Workers' Compensation Act is a statutory workers' compensation scheme that covers most dock workers and maritime workers not otherwise covered by the Jones Act. We therefore did not expect to capture fishing HRI claims in our study.

HRI Case Identification

HRI cases were identified using a two-step process. First, workers' compensation claims were identified from State Fund workers' compensation claims databases using a data systems definition. Second, identified claims underwent investigator review to confirm that the claim was filed for HRI.

Data Systems Definition—The HRI data systems definition used information on industries, injuries and illnesses, and diagnoses. Industries were identified using North American Industrial Classification System (NAICS), Standard Industrial Classification (SIC), and L&I Risk Class coding. Washington employer accounts are assigned a NAICS code [US Department of Commerce, 2012] based on their principal economic activity. Although NAICS was adopted in 1997 to replace the SIC coding [US Department of Labor, 2012], Washington accounts are coded using both NAICS and SIC. Workers' compensation premiums are based on Washington's risk classification system. Risk classes identify business operations that carry similar risk for industrial insurance losses [WA L&I, 2009].

Washington L&I claims with the industry/sector codes listed in Table I were identified. From these claims, potential HRI cases with injury dates between January 1, 1995 and December 31, 2009 were identified on March 22, 2013 using injury, illness, and diagnosis codes. Prior to July 1, 2005, L&I used American National Standards Institute (ANSI) Z16.2 codes to classify injuries and illnesses based on the injury or illness narrative description submitted by the worker and physician on the workers' compensation claim form [ANSI, 1969]. Injury and illness coding changed from ANSI to Occupational Injury and Illness Classification System (OIICS) codes for claims filed after July 1, 2005. International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9) codes are assigned by medical providers and hospitals to bills submitted to L&I. Workers' compensation claims administrators must also assign ICD-9 codes to individual claims to authorize bill payment. This study was restricted to State Fund claims because ICD-9 codes are not available for self-insured claims, and there is limited medical information for self-insured claims that do

not result in payment for time-loss (lost work time due to work-related injury or illness after a three day waiting period).

Potential HRI cases for claims up to July 1, 2005 were defined as having an ANSI Z16.2 type code of 151 (Contact with general heat—atmosphere or environment) and/or any of the ICD-9 codes listed in Table II. Potential HRI cases for claims on or after July 1, 2005 were defined as having an OIICS Source Code of 9362 (Temperature extremes—environmental – heat) or OIICS Nature Code 072* (Effects of heat and light) or OIICS Event Code 321 (Exposure to environmental heat) and/or any of the ICD-9 codes listed in Table II.

Investigator Review—For claims meeting the HRI data systems definition, we extracted worker, physician and employer electronic claim text fields describing the injury on the Report of Industrial Injury and Occupational Disease form. To initiate a workers' compensation claim in Washington, this form must be completed by both the worker and healthcare provider and submitted to L&I. Two investigators (JTS, JK) independently reviewed electronic claim text fields to determine whether the claim was consistent with HRI. If the information in text fields was insufficient or absent, the medical record for the claim was reviewed to determine whether the claim was consistent with an HRI in the setting of exertion and/or hot work conditions (excluding fires). Medical records for workers' compensation claims are scanned into L&I databases and are available for review. If there was initial disagreement between the two reviewers, a determination was made by reviewing claim text fields and data from medical records.

Of the 172 claims identified using the data systems definition, 84 were classified as HRI claims after medical review of the electronic claim text fields and medical records and were therefore included in the final analysis. Eighty-eight claims satisfied the data systems definition as HRI claims but on investigator review were not determined to be HRI cases. Of these 88 claims, two were excluded because symptoms occurred in the setting of a fire, one burn case was excluded, and two nosebleed and two motor vehicle accident cases not clearly related to workplace heat exposures were excluded.

The remaining 81 claims were identified solely with ICD-9 codes. Seven plant dermatitis cases were likely miscoded as 992.6—Heat fatigue, transient (plant dermatitis is correctly coded as 692.6). Approximately 30 trunk contusions were likely miscoded as heat-related diagnoses 992.X (correct trunk contusion codes include 922.X). There was no apparent systematic misclassification of the remaining 44 claims, and these likely represent data entry errors by claims administrators.

Characteristics of HRI Claims

Demographic Information, Industry Groups, Time-loss, and Costs—Data obtained for each claim included the unique claim identification number, the claimant's date of birth and gender, ANSI Z16.2 and OIICS codes, the date and hour of injury, Washington risk class, NAICS, and SIC codes, the claimant's occupation code according to the 2000 Standard Occupational Classification system [US Department of Labor, 2010], the duration of employment with the employer of record, the claim status code, ICD-9 codes, and the cost of the claim. For comparison purposes, similar data, if available, were collected for all

accepted Agriculture, Forestry, and Fishing sector claims and all accepted State Fund claims during the study period.

Workers' compensation claim costs represent those paid to date for closed claims. For those claims that remained open on the date of extraction, the claim costs represent those paid to date and an estimate by the L&I workers' compensation case reserve unit of future expected claim costs. Indirect costs to employers and workers and the administrative costs of managing the claim are not included in the claim costs.

Both compensable and non-compensable claims were included in the study. Compensable claims are those with the claim status code as either 'compensable,' 'kept-on-salary,' 'total permanent disability,' 'fatal,' or 'loss of earning power.' A claim is assigned a 'compensable' claim status code if it involves lost work time due to work-related injury or illness after a three day waiting period (time-loss). Time-loss data were also obtained for each claim.

We grouped claims meeting the HRI case definition into the following *a priori* industry categories: 1) crop production & support (NAICS 111 or 1151; or main WA risk class 4802, 4803, or 4813); 2) forestry & logging support (NAICS 113 or 1153); and 3) landscape & horticultural services (NAICS 56173 or SIC 078).

Indoor versus Outdoor Claims—We determined whether heat exposure occurred in an outdoor work environment. The definition of outdoor was based on the Washington Agriculture Heat Rule (WAC 296-307-097*), which defines the outdoor environment as an environment where work activities are conducted outside [WA Administrative Code, 2009]. In this definition, work environments such as inside vehicle cabs, sheds, and tents or other structures may be considered an outdoor environment if the environmental factors affecting temperature are not managed by engineering controls. Activity is considered to be work in an indoor environment when performed inside a structure with walls and a roof.

County of Injury—Information about the county of injury was manually extracted from the Report of Industrial Injury and Occupational Disease form "address where injury or exposure occurred" field. If the county of injury was missing but the clinic or hospital that the worker first visited was in the same county as the county of the employer's business location, then the county of the employer's business location was used to impute the missing county of injury. After performing this imputation, the county of injury was missing for six claims. Excluding missing observations, the county of injury was different from the county of the employer's business location for 22 claims (percent agreement approximately 70%). For seven of these 22 claims, the county of injury and the county of the employer's business location were not contiguous. Although less complete, we decided to use the imputed county of injury rather than the county of the employer's business location in our analyses because we assumed that use of the county of injury would yield more accurate weather estimates.

Weather Data—Historical weather data were obtained from AgWeatherNet, which provides access to current and historical weather data from Washington State University's automated weather station network [WSU, 2013]. AgWeatherNet includes 151 automated

weather stations throughout Washington. Monitoring stations are comprised of various sensors that measure weather variables, including temperature and relative humidity, which are recorded every five seconds and summarized every 15 minutes by data loggers (Campbell Scientific CR-1000). Following data processing, weather data are disseminated via the website weather.wsu.edu. AgWeatherNet is managed by a team located at the Washington State University Irrigated Agriculture Research and Extension Center in Prosser, Washington. The team follows strict protocols for the siting of weather stations based on local terrain and other factors. Quality control activities are conducted regularly, and sensors are calibrated on a routine basis to ensure data are accurate.

For outdoor HRI claims, we extracted temperature data from AgWeatherNet and calculated the maximum and minimum temperatures (T_{max}, T_{min}) and temperature range ($T_{max} - T_{min}$) for each county of injury on the date of injury. We also extracted relative humidity (RH) percents and calculated heat indices (HI) for each county of injury on the day of injury using concurrent T and RH measures. The HI was calculated, using Rothfusz's modification of Steadman's work, as: $HI = -42.379 + 2.04901523^{*}T + 10.14333127^{*}RH - 0.22475541^{*}T^{*}RH - 6.83783^{*}10^{-3*}T^{2} - 5.481717^{*}10^{-2*}RH^{2} + 1.22874^{*}10^{-3*}T^{2*}RH + 8.5282^{*}10^{-4*}T^{*}RH^{2} - 1.99^{*}10^{-6*}T^{2*}RH^{2}$ [Steadman, 1979; Rothfusz, 1990]. The maximum HI (HI_{max}) was determined for each county of injury on the day of injury. Of note, the HI cannot be calculated for temperatures less than 80°F. For counties with multiple weather stations, available data from all weather stations in that county on the day of injury were averaged to determine the daily mean T_{max}, $T_{min,}$ and $HI_{max.}$

The number of AgWeatherNet stations and outdoor HRI cases by county of injury are shown in Appendix I. Weather stations were not available in four counties of injury, where six HRI cases occurred. For eight additional outdoor HRI cases, AgWeatherNet stations were not installed until after dates of injury. Forty-five of 59 outdoor HRI cases were therefore included in the final weather analysis. In a secondary analysis, we used data from the nearest county with available weather stations to impute weather data in counties without weather station data at the time of injury. In cases where there were multiple adjacent counties, data from the county with largest shared border were used for the imputation.

Diagnosis Groups—We grouped claims into the following *a priori* diagnosis groups based on ICD-9 codes: 1) heat rash (ICD-9 705.1); 2) heat syncope, heat cramps, heat exhaustion, heat edema, heat fatigue, other heat effects (ICD-9 992, 992.1, 992.2, 992.3, 992.4, 992.5, 992.6, 992.7, 992.8, 992.9); 3) dehydration, hyperosmololality/hypernatremia, hypovolemia/volume depletion, other (ICD-9 276.0, 276.5, 276.50, 276,51, 276.52); and 4) heat stroke, acute renal failure (ICD-9 992.0, 584, 584.9).

HRI Severity—For claims meeting the HRI case definition, we reviewed the workers' compensation claim medical and administrative records for the following information. We determined the severity of each claim as: 1) treated as outpatient; 2) requiring inpatient hospitalization but not intensive care; 3) requiring intensive care; or 4) died.

Clinical & Other Potential HRI Risk Factors and Consequences—From the available medical records, we determined whether there existed potential risk factors related

to HRI medication/supplement/drug use and/or a concurrent medical condition [Bonauto et al., 2007]. Medications and supplements considered to be potential HRI risk factors included medications for allergy (antihistamines), cough and cold (anticholinergics), nausea (anticholinergics), blood pressure and heart conditions (alpha adrenergic blockers, beta blockers, calcium channel blockers, diuretics), irritable bowel/bladder (anticholinergics), mental health conditions (benzodiazepines, neuroleptics, tricyclic antidepressants), seizures, thyroid conditions, laxatives, and diet pills/stimulants (amphetamines, diuretics, caffeine, nicotine). Possible illicit drug use and alcohol use on or during the days preceding the HRI claim were also considered as potential risk factors. Concurrent medical conditions considered as potential HRI risk factors included cardiovascular disease, psychiatric conditions, infection/fever, diabetes, lung disease, or previous episodes of HRI. We calculated body mass index (BMI) as self-reported weight [kg]/self-reported height $[m]^2$. Finally, we noted any other potential HRI-related characteristics of interest described in the claim text fields, including injuries related to heat exposure, shade availability, hydration and clothing issues, competing hazards, and method of payment for work (e.g. piece rate).

Heat-Related Inspection Report Identification

Washington Division of Occupational Safety and Health inspection reports were accessed on January 31, 2013 using the Washington Industrial Safety and Health Act Inspection Network system. This is a web-based system for tracking safety inspections and citations for the Washington Division of Occupational Safety and Health. Inspection reports were included if they resulted in a citation for violation of the Washington Agriculture Heat Rule [Washington Administrative Code (WAC) 296-307-097*] [WA Administrative Code, 2009] and if violations were between 2009 and 2012 (the WA Heat Rule was implemented in 2008). Sixty inspection reports were included in the final analysis.

Characteristics of Heat-Related Inspection Reports

Data obtained for each inspection report included the unique violation identification number, violation text, the NAICS code for the employer's account, and the specific part of the Washington Agriculture Heat Rule violated [e.g. heat safety in accident prevention program (296-307-09730-1-1); encourage employees to frequently consume acceptable beverages (296-307-09730-1-2); ensure sufficient drinking water (296-307-09740-1-1); respond to employees with signs and symptoms of HRI (296-307-09750); worker HRI training (296-307-09760-1); and supervisor HRI training (296-307-09760-2)].

Analyses

Descriptive statistics and histograms were generated for HRI claim characteristics and Washington Agriculture Heat Rule citation characteristics. Daily temperature differences in different industry subgroups were compared using unpaired Student's *t*-tests, assuming unequal variances. The proportions of male agriculture and forestry HRI claimants in different industry subgroups were compared using *z*-tests of two proportions.

Geographical distributions of HRI claims by county were generated using Google Fusion Tables [Google, 2013]. Fusion Tables is a data visualization web application that allows gathering and visualization of data tables. Using Fusion Tables, frequencies of HRI claims

by county were combined with publicly-available Kehole Markup Language-encoded Washington county information. Keyhole Markup Language is a notation for expressing geographic annotation and visualization within Internet-based maps, such as Google Maps.

Claim incidence rates were calculated by agriculture and forestry HRI NAICS, SIC, risk class group and year and are expressed as the number of claims per 100,000 full-time equivalents (FTEs). Employers within the Washington State Fund are required to report the cumulative number of hours worked by their employees on a quarterly basis. It was assumed that one FTE is equivalent to 2,000 work hours.

All analyses were performed using Stata 11 (StataCorp, College Station, TX) and SAS 9.3 (SAS Institute Inc., Cary, NC). The Washington State Institutional Review Board reviewed and approved the study protocol.

RESULTS

HRI Workers' Compensation Claims

There were 84 accepted Washington State Fund HRI claims in the agriculture and forestry sectors between January 1, 1995 and December 31, 2009 (Table III). Approximately 178,000 agriculture and forestry and 2 million State Fund claims total occurred during this period. The majority of agriculture and forestry HRI claims (73%) were third quarter claims (July, August, or September dates of injury).

Seventy-six of the 84 HRI claims (90%) were classified as 'non-compensable' (medical only), and 8 (10%) were 'compensable' (involving ≥ 4 lost work days, a permanent partial disability award, being kept on-salary by the employer, loss of earning power, or a fatality). Approximately 25% of all Washington State Fund claims during this period were compensable.

The mean (median) cost per claim for all agriculture and forestry HRI claims was $3,502 ($654) and for non-compensable agriculture and forestry HRI claims was $3,071 ($568) (Table IV). In comparison, the mean (median) cost per claim for all non-compensable agriculture and forestry claims and all non-compensable State Fund claims was $655 ($287) and $744 ($289), respectively. The mean (median) cost for severe agriculture and forestry HRI claims (involving inpatient hospitalizations) or deaths was $24,533 ($6,536). The mean (range) number of time-loss days for severe HRI claims was 25 (0–96) days.

Figure 1 shows frequencies and incidence rates of HRI agriculture and forestry claims over the study period. The average annual incidence rate per 100,000 FTE for all claims was 7.0 and for third quarter claims was 15.7. In general, after a relative peak in 1998, there has been a trend of an increase in the frequency of claims between 2000 and 2009.

Industry Groups and Demographic Characteristics—As expected, no fishing industry HRI claims were captured in our analysis. The majority (61%) of agriculture and forestry HRI claims during the study period was in crop production and support, and farm workers and laborers were the occupational group with the highest percentage of claims (Table III). Seventeen percent of claims occurred in landscape and horticultural services, and

17% occurred in forestry and logging support. The occupational groups with the highest percentage of HRI claims in these industry subgroups were landscaping and grounds-keeping workers and logging workers, respectively.

The median age of agriculture and forestry HRI claimants was 30 [interquartile range (IQR) 23 to 46] years (Table III). The median (IQR) ages for all agriculture and forestry and all State Fund claimants during the study period were 33 (25–43) and 35 (26–45), respectively. The majority of agriculture and forestry HRI claimants were male (76%), compared to 79% for all agriculture and forestry and 71% for all State Fund claims. The proportion of male HRI claimants in the crop production and support subgroup (65%) was lower than for agriculture and forestry claimants in the other subgroups (z=-3.06, $p = 0.002$).

The median length of employment for agriculture and forestry HRI claimants was 91 days, compared to 304 days for all agriculture and forestry claimants and 365 days for all State Fund claimants during the study period. Approximately 15% of agriculture and forestry HRI claimants had been working at their job of injury for less than two weeks.

Environmental, Temporal, and Geographic Factors—Eight percent of all agriculture and forestry HRI claims and 8% of crop production and support HRI claims during the study period occurred during indoor work (Table III). The distribution of agriculture and forestry HRI claims by month of injury for indoor and outdoor claims is shown in Figure 2. Ninety five percent of outdoor claims occurred between May and September, and 84% occurred between June and August. The distribution of claims by hour of day is shown in Figure 3. The majority of outdoor HRI resulting in claims occurred between 11 am and 3 pm.

The mean (IQR) T_{max} for outdoor agriculture and forestry HRI claims was 95 (89, 100) °F, and the mean (IQR) HI_{max} was 99 (90, 106) °F (Table III). Results from a secondary analysis, in which data from nearby counties were used to impute weather data in counties without weather station data at the time of injury, were comparable [mean (IQR) T_{max} 94 (88, 100) °F, mean (IQR) HI_{max} 97 (89, 104) °F]. The mean (standard deviation) difference between daily T_{max} and T_{min} was 42 (11) °F. The mean temperature difference was higher for crop production and support claimants (43 °F) than for claimants in other subsectors ($t(36)=3.56$, $p = 0.001$). The mean T_{max} for outdoor agriculture and forestry HRI claims by month is shown in Figure 4. The mean T_{max} was highest in July and August.

The geographical distribution of agriculture and forestry HRI claims by county of injury is shown in Figure 5. The largest number of claims occurred in Central Washington in Yakima (13 claims), Grant (10 claims), and Benton (7 claims) counties, though claims also occurred in the Eastern and Western parts of the State.

Clinical Factors—The majority (73%) of agriculture and forestry HRI claims had diagnosis codes corresponding to heat syncope, heat cramps, heat exhaustion, heat edema, or heat fatigue (Table V). Fifteen percent of claims were characterized by heat stroke or acute renal failure diagnoses. There was only one heat rash claim. The majority of claims (89%) were not severe (treated as outpatient), but five claims (6%) required intensive care, and there was one death. As shown in Figure 1, severe claims (involving inpatient

hospitalizations) and deaths occurred during several years prior to 2007. The frequency of less severe claims subsequently increased.

In 15% of claims, medications, supplements, or alcohol/drugs, which could serve as potential HRI risk factors, were recorded. In 19% of claims, concurrent medical conditions or previous HRI, which could also serve as potential HRI risk factors, were recorded. The median (IQR) BMI of agriculture and forestry HRI claimants was 26 (23, 29).

Other Potential HRI Risk Factors and Consequences—We noted other potential HRI-related characteristics of interest described in claim text fields. Several claims mentioned lack of shade as a condition surrounding the HRI event. A long distance to water or inadequate water supplies in the field were also described for several claims. Several claims also mentioned that workers were wearing personal protective equipment, including respirators and protective suits, when the worker developed HRI. One claim noted the piece rate nature of workers' work, and one claim specifically noted a source of radiant heat (asphalt) at the workplace. Several claims mentioned accidents, such as falls from heights that occurred in workers who felt hot, sweaty, and dizzy.

Heat-Related Inspection Reports

There were 60 citations for Washington Agriculture Heat Rule violations among 28 unique businesses between 2009 and 2012. Citations occurred primarily for lack of worker training (WAC 296-307-09760-1) (45%) or a lack of a heat safety plan in the accident prevention program (WAC 296-307-09730-1-1) (35%) (Table VI). Only two citations (3%) were given for lack of drinking water availability (WAC 296-307-09740-1-1). The majority (75%) of WA Heat Rule citations occurred in crop production and support (NAICS 111 or 1151). Twenty-eight percent of Washington Heat Rule citations occurred in nursery and tree production (NAICS 111421). One quarter of citations occurred in other non-citrus fruit farming (NAICS 111339), and 22% occurred in wineries (NAICS 312130). The number of violations and unique businesses (by business location) with violations is shown in Figure 6. In general, the number of violations has declined since 2009.

DISCUSSION

We report on 84 Washington agriculture and forestry HRI workers' compensation claims of varying severity from 1995 to 2009 and 60 Washington Agriculture Heat Rule citations from 2009 to 2012. This is the first published report that we are aware of that includes a systematic description of Heat Rule violations. Although the number of severe agriculture and forestry HRI cases appear to be declining, a substantial burden of non-fatal cases is present. These cases are characterized by potential work-related, environmental, and personal HRI risk factors.

HRI Claims Costs and Trends

Although we observed a relatively small number of agriculture and forestry HRI workers' compensation claims compared to all Washington agriculture and forestry and State Fund claims during the study period, our results indicate that HRI in agriculture and forestry is an

important public health problem. Approximately 15% of claims involved serious health effects, including heat stroke and acute renal failure, and 11% involved inpatient hospitalizations or deaths. Non-compensable claims were more common than compensable claims, and mean costs of these claims were greater than for all non-compensable agriculture and forestry and total non-compensable State Fund claims. Mean non-compensable agriculture and forestry HRI costs were also higher than for non-compensable Washington State Fund HRI claims in all industries between 1995 and 2005 [Bonauto et al., 2007]. Occupational HRI cases are probably significantly more common than workers' compensation claims data suggest, as they are likely under-recognized by workers and health-care providers and under-reported to the workers' compensation system [Bonauto et al., 2007].

The increase in the frequency of agriculture and forestry HRI claims observed between 2000 and 2009 is difficult to interpret. This increase may be due to an increased awareness and reporting of HRI cases to the workers' compensation system or may reflect an actual increase in the frequency and rate. The reported number of hours worked by employees has not decreased over time. Fortunately, there were no severe claims, involving inpatient hospitalizations and deaths, in Washington after 2006.

The effectiveness of the Washington Agriculture Heat Rule, and the reasons for the overall decline in Heat Rule citations between 2009 and 2012, are also difficult to determine. It is possible that implementation of the Heat Rule in 2008, and increased HRI awareness leading up to implementation, may have contributed to the decrease in the frequency of severe HRI cases subsequently. However, it seems unlikely that the relatively small number of citations for relatively weak controls such as worker and supervisor HRI training or including heat safety in accident prevention programs could alone have led to a direct decrease in the number of severe HRI cases. Enforcement of the Heat Rule may be difficult because, unlike the presence of physical or chemical hazards, it is difficult to confirm that employers are not encouraging employees to frequently consume acceptable beverages or not responding to employees with signs and symptoms of HRI. The impact of educational efforts conducted by business, labor, academic and government groups to increase awareness of HRI risk factors among at-risk populations, and whether these educational efforts contributed to a decline in severe HRI cases, is currently unknown.

Potential HRI Risk Factors

We described several different types of potential HRI risk factors, including work-related, environmental and geographic, and personal risk factors identified in Washington workers' compensation claims and Heat Rule citation data.

Work-Related Factors—The majority of agriculture and forestry HRI claims in our study were in crop production and support subsectors. This finding is consistent with national data, which indicate a high risk of fatal HRI in crop production and support [BLS, 2011; Jackson and Rosenberg, 2010]. Washington Agriculture Heat Rule citations between 2009 and 2012 also occurred largely in crop production and support, perhaps in response to the industry

subsector characteristics of agriculture and forestry workers' compensation HRI claims that occurred prior to 2009.

Other potential work-related HRI risk factors noted in claim text fields, including lack of shade, use of certain personal protective equipment, long distance to drinking water or inadequate water supplies, and piece rate nature of work have also been previously described [Jackson and Rosenberg, 2010; Lam et al., 2013]. Although the California Heat Rule addresses shade [CA DOSH, 2006], the Washington Agriculture Heat rule does not [WA Administrative Code, 2009]. Addition of workplace shade requirements to regulations should be considered. The Washington Agriculture Heat Rule does require worker education on the importance of removing heat-retaining personal protective equipment during all breaks [WA Administrative Code, 2009], although the frequency of removal depends on the frequency of breaks allowed by the employer.

The Washington Agriculture Heat Rule also requires that employers ensure that all employees have the opportunity to drink at least one quart of water per hour [WA Administrative Code, 2009]. There were two Heat Rule citations for lack of available drinking water (Washington Administrative Code 296-307-09740-1-1). Further, in a *post hoc* analysis of Washington Field Sanitation Rule (Washington Administrative Code 296-307-0951) citations between 2009 and 2012, we noted several citations for lack of potable water (296-307-09512-8) and lack of toilet facilities (296-307-09518). Even if available, barriers to water consumption at work likely exist, including lost wages from taking breaks among piece rate workers, negative reactions from supervisors regarding water breaks, and lack of nearby bathroom facilities [Stoecklin-Marois et al., 2013]. Effective hydration strategies likely require not only mandating that employers provide drinking water at work, but also addressing specific barriers to water consumption.

Work-related HRI prevention strategies require employer support and involvement. Workers have minimal control over certain work-related HRI risk factors, such as workplace shade availability and proximity to bathrooms and water facilities. Engaging with employers in the discussion and development of HRI prevention strategies may increase the chance of effectively addressing barriers to HRI prevention.

Environmental and Geographic Factors—The majority of agriculture and forestry HRI claims occurred during outdoor work between June and August, as has been previously described for Washington HRI claims [Bonauto et al., 2007], and between the hours of 11 am and 3 pm. Mean T_{max} values were greatest during these summer months. The mean T_{max} for outdoor Washington agriculture and forestry HRI claims (95 °F) was greater than that previously reported for all outdoor WA HRI claims (85 °F) [Bonauto et al., 2007]. Reasons for this difference include our focus specifically on agriculture and forestry HRI claims rather than all HRI claims and our use of the imputed injury of location rather than the employer's business location to estimate temperatures, which may have led to more accurate temperature estimates.

The mean HI_{max} was 99°F for outdoor agriculture and forestry HRI claims, which corresponds to a moderate (versus high or very high/extreme) risk of HRI in outdoor

workers [US OSHA]. The physiological response to dissipate heat and maintain a normal core body temperature (heat strain), which is overwhelmed in exertional HRI, can still occur in relatively cool environments, depending on the amount of metabolic heat produced [Jackson and Rosenberg, 2010]. Exertional heat illness depends not only on environmental heat but also on metabolic heat produced during strenuous work, such as certain agriculture and forestry work. Approximately one quarter of outdoor HRI cases occurred below a mean HI_{max} of 90°F, indicating a substantial HRI risk even at a level that may be labeled “lower risk” in certain existing schemes [US OSHA].

The mean difference in daily T_{max} and T_{min} was 42°F, and this difference was significantly higher for crop production and support claimants than for claimants in other subsectors. In a recent qualitative study of HRI in Latino farm workers in Washington, workers reported that they often did not take all extra clothing layers off as the day became progressively warmer, and that they felt that layers helped keep them cool by inducing sweating [Lam et al., 2013]. It is possible that a greater range in daily temperatures results in worker behaviors of wearing extra layers during earlier cooler parts of the work day that are later not removed, leading to trapping of heat, prevention of evaporative cooling, and an increased risk of HRI.

The largest number of agriculture and forestry HRI claims occurred in Central Washington, including in Yakima, Grant, and Benton counties. Central Washington is characterized by a large market value of crops and a large number of farms compared to other parts of the State [WA Department of Agriculture, 2013]. Central Washington also has a dry, semi-arid climate, unlike areas west of the Cascade Mountain Range.

Personal Risk Factors—Heat acclimatization is a temporary physiological adaptation that improves dissipation of heat and heat tolerance [Jackson and Rosenberg, 2010]. Workers can become acclimatized to heat if they work in hot weather for at least two hours per day for four to 14 days, but acclimatization reverses in the days after work in hot conditions ceases [Jackson and Rosenberg, 2010]. Approximately 15% of agriculture and forestry HRI claimants had been working at their job of injury for less than two weeks. However, we did not collect data on environmental conditions leading up to the HRI incident. Nor was data available on non-work activities and environmental conditions, including in worker housing settings, which may also influence acclimatization [Quandt et al., 2013]. Acclimatization could be further investigated in future studies that systematically characterize relevant work and non-work environmental conditions and activities over time.

In contrast with classical heat stroke, exertional HRIs such as heat cramps, heat syncope, heat exhaustion, and heat stroke can occur in young workers, particularly those performing physically demanding work in hot and humid environments. Washington agriculture and forestry HRI claimants were relatively young (median age 30 years) males, consistent with previous reports [Bonauto et al., 2007; Jackson and Rosenberg, 2010]. However, agriculture and forestry HRI claimants in crop production and support were older and more likely to be female than claimants in other subsectors.

Farm workers and laborers were the occupational group with the highest percent of agriculture and forestry HRI claims. The US Agriculture, Fishing, and Forestry sector

employs over two million workers, and about half of these workers are employed in the crop production subsector [BLS, 2012]. Hired farm workers in the US are largely seasonal, foreign-born, Spanish-speaking workers [US Department of Labor, 2005]. Latino farm workers may be at higher risk for negative occupational health and safety outcomes, including HRI, due to extreme work conditions, reliance on employer beneficence, and cultural barriers [Culp et al., 2011]. We were not able to specifically describe race and ethnicity in our study, as this information is not captured in Washington L&I databases.

Certain comorbid medical conditions, previous HRI, and medications, supplements, or drugs that dehydrate, increase heat production, or inhibit cooling have been described as risk factors for HRI [Jackson and Rosenberg, 2010]. In 19% of claims in our study, comorbid medical conditions or previous HRI were recorded, and the median BMI of claimants was 26, corresponding to overweight status (BMI ≥ 25). However, comorbid medical conditions and medications were not always systematically recorded in L&I's databases, and BMI values were missing for a large percentage of claims. Systematic and more complete collection of comorbid medical conditions, medications, and BMI is needed to further investigate the relationship between these potential risk factors and HRI.

Heat Exposure and Injuries

Text fields of several agriculture and forestry HRI claims mentioned injuries, such as falls from heights, which occurred in workers that felt hot, sweaty, and dizzy, and who were likely dehydrated. Decrements in vigilance and endurance during heat exposure have been described [Enander, 1989]. In addition, high ambient temperatures and heavy workloads have been reported to be associated with unsafe work behaviors [Ramsey et al., 1983]. Several epidemiologic studies have suggested a relationship between occupational heat stress and injury using self-reported assessments of heat stress or crude measures of heat exposure [Morabito et al., 2006; Tawatsupa et al., 2013; Fogleman et al., 2005]. Accurate estimates of local environmental conditions using sophisticated modeling techniques and further study of the relationship between environmental estimates, HRI, and occupational injuries are needed.

Limitations

Our study has several important limitations. First, in this descriptive study, we did not quantify the association between potential HRI risk factors and HRI. Second, our use of imputed injury location to estimate temperatures and Heat Index values at the county level, and the lack of weather stations in certain counties at certain times, likely yielded only crude estimates of exposure. We believe that using imputed injury locations is more accurate than solely using the employer's physical business location. We did not collect data on environmental conditions leading up to the HRI incident or on non-work-related environmental activities and conditions, which are important in the evaluation of acclimatization. Third, as previously described, there is likely under-reporting of HRI to the workers' compensation system. In addition, we focused on Washington State Fund claims and did not include HRI claims of workers employed at companies that self-insure, federal government workers, workers covered by alternative workers' compensation systems, and those workers exempted from mandatory workers' compensation coverage in Washington

State (e.g., self-employed workers, household workers, and others). The generalizability of our findings to other states and countries is not known.

Conclusions

Agriculture and forestry HRI cases are characterized by potential work-related, environmental, and personal risk factors. Collaboration with employers and workers to reduce modifiable risk factors, such as lack of shade, barriers to adequate worker hydration, lack of acclimatization, lack of recommended clothing, and high metabolic heat production in hot conditions may help reduce the risk of HRI. Efforts should be focused on high-risk industry subsectors and geographical areas, such as crop production and support, during high-risk times of year. Further work is needed to elucidate the relationship between potential health effects of heat exposure beyond HRI, including occupational injuries.

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Appendix I: Outdoor heat-related illness claims and AgWeatherNet stations by county of injury

County of injury	# HRI claims, 1995–2009	# AgWeatherNet weather stations	Year of first HRI claim, 1995–2009	Year of first weather station installation
Benton	6	27	1995	1989
Chelan	2	7	1996	1993
*Ferry	1	0	2000	-----
Franklin	8	9	1995	1989
Grant	9	15	1998	1989
Grays Harbor	2	1	2008	2008
*King	5	2	1998	2008
*Kitsap	1	1	2009	2013
*Lewis	2	0	1999	-----
*Mason	1	0	1998	-----
*Okanogan	1	9	1998	1999
Pierce	1	1	1995	1995
Skagit	2	3	2004	1993
*Snohomish	2	1	1995	2006
*Stevens	2	0	1997	-----
Walla Walla	2	7	2006	1989
Whatcom	2	4	2006	2002
Yakima	10	18	1997	1989

Heat-related illness (HRI)

*Counties without an AgWeatherNet weather station installed before date of first HRI claim

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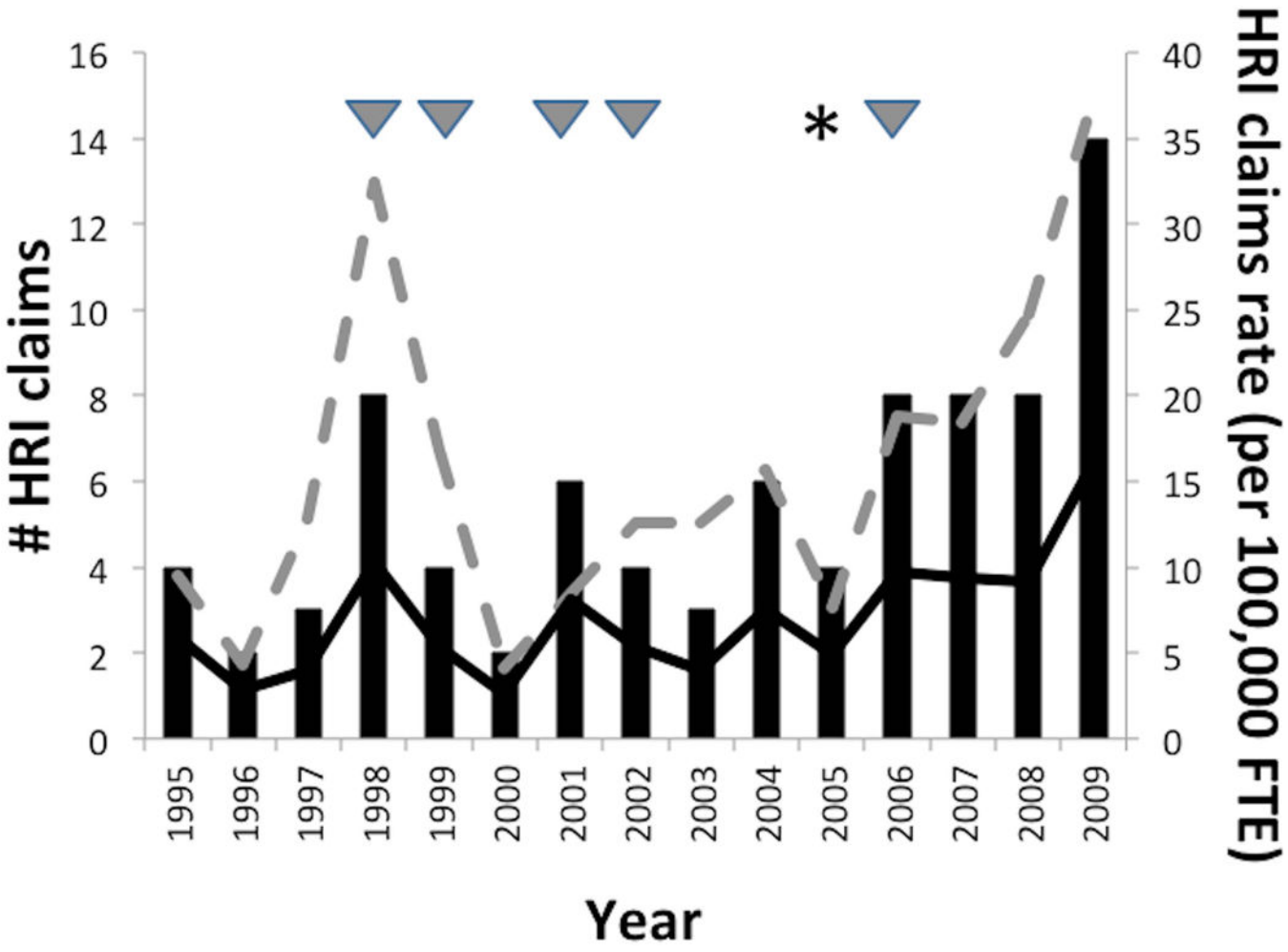

Figure 1. Washington State Fund agriculture and forestry workers' compensation heat-related illness (HRI) claims and claims incidence rates by year, 1995–2009

Black bars: number of HRI claims; Solid line: annual HRI claims incidence rates per 100,000 full-time equivalents (FTE); Dotted line: annual third quarter (July, August, and September dates of injury) HRI claims rates; triangles above bars: years characterized by severe claims (inpatient hospital admissions but not deaths); Asterisk above bar: year in which a death occurred.

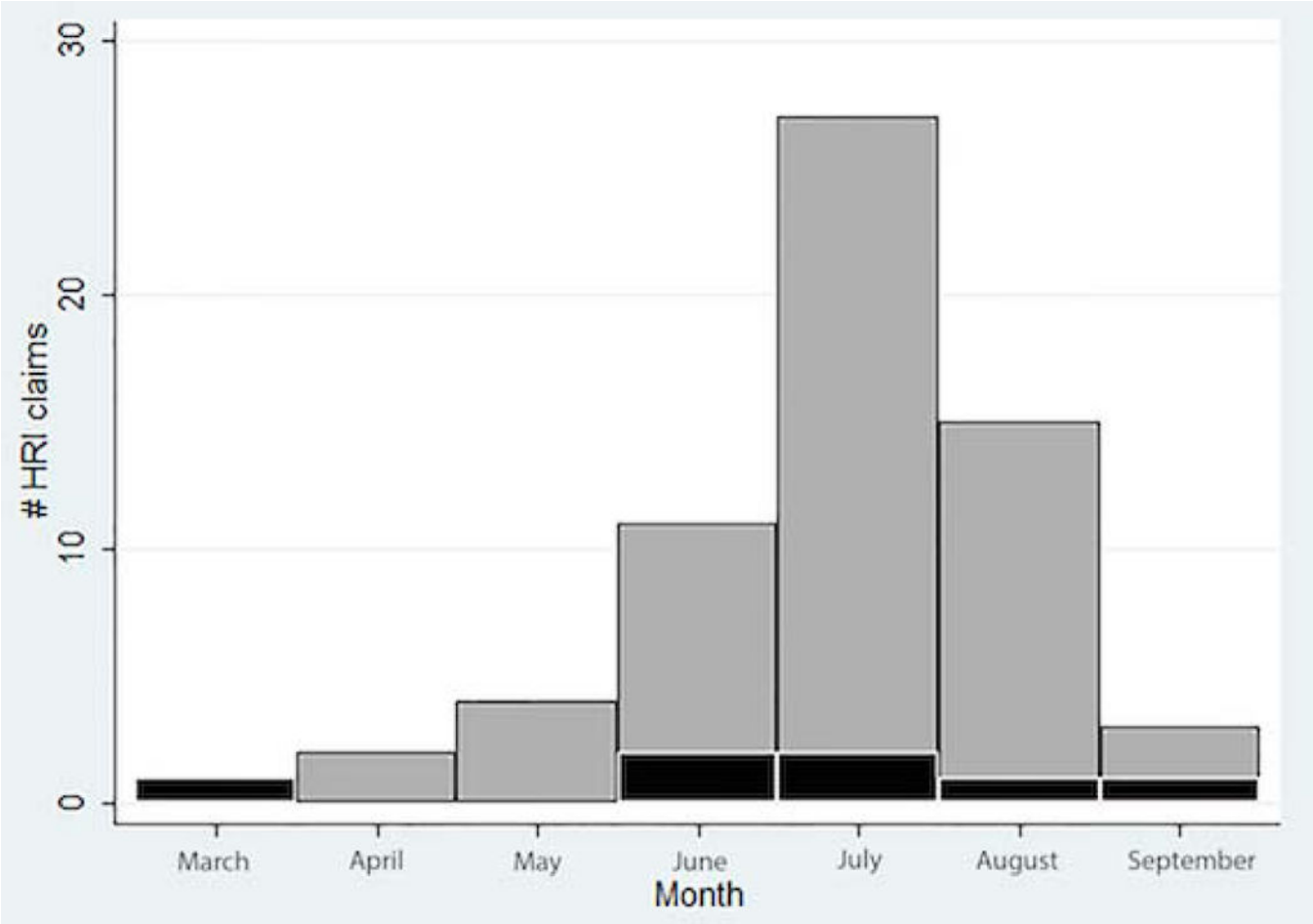

Figure 2. Washington State Fund agriculture and forestry workers' compensation heat-related illness (HRI) claims by month of injury, 1995–2009

Gray bars: outdoor; Black bars: indoor.

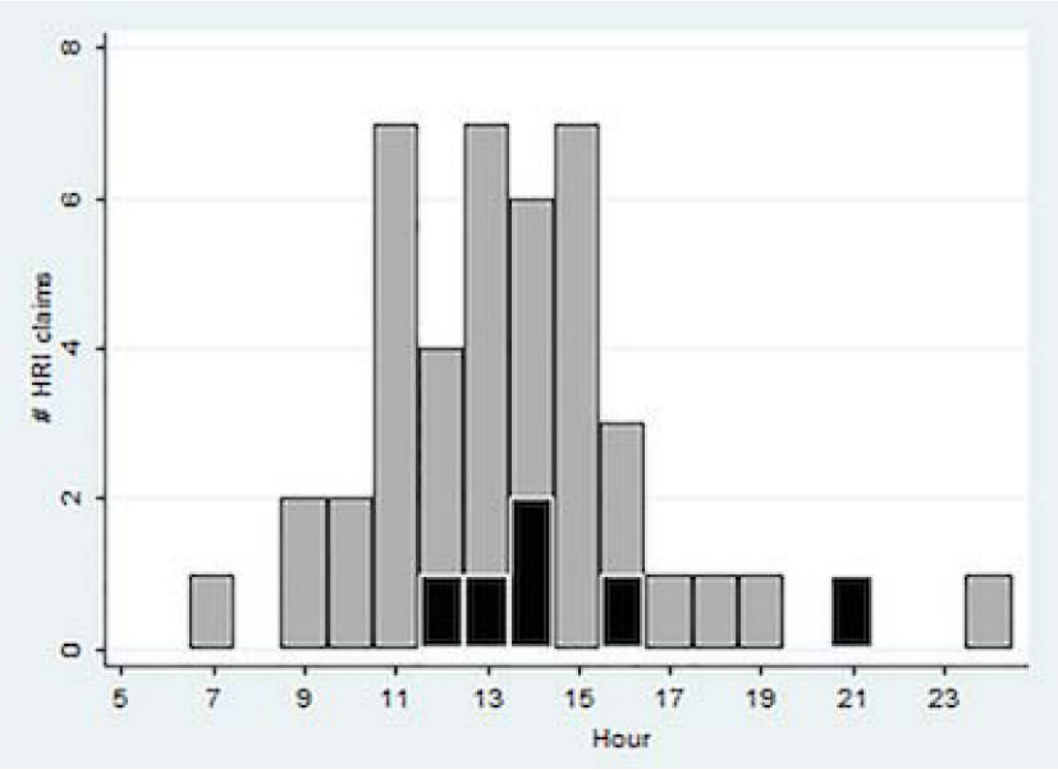

Figure 3. Washington State Fund agriculture and forestry workers' compensation heat-related illness (HRI) claims by hour of day, 1995–2009

Gray bars: outdoor; Black bars: indoor

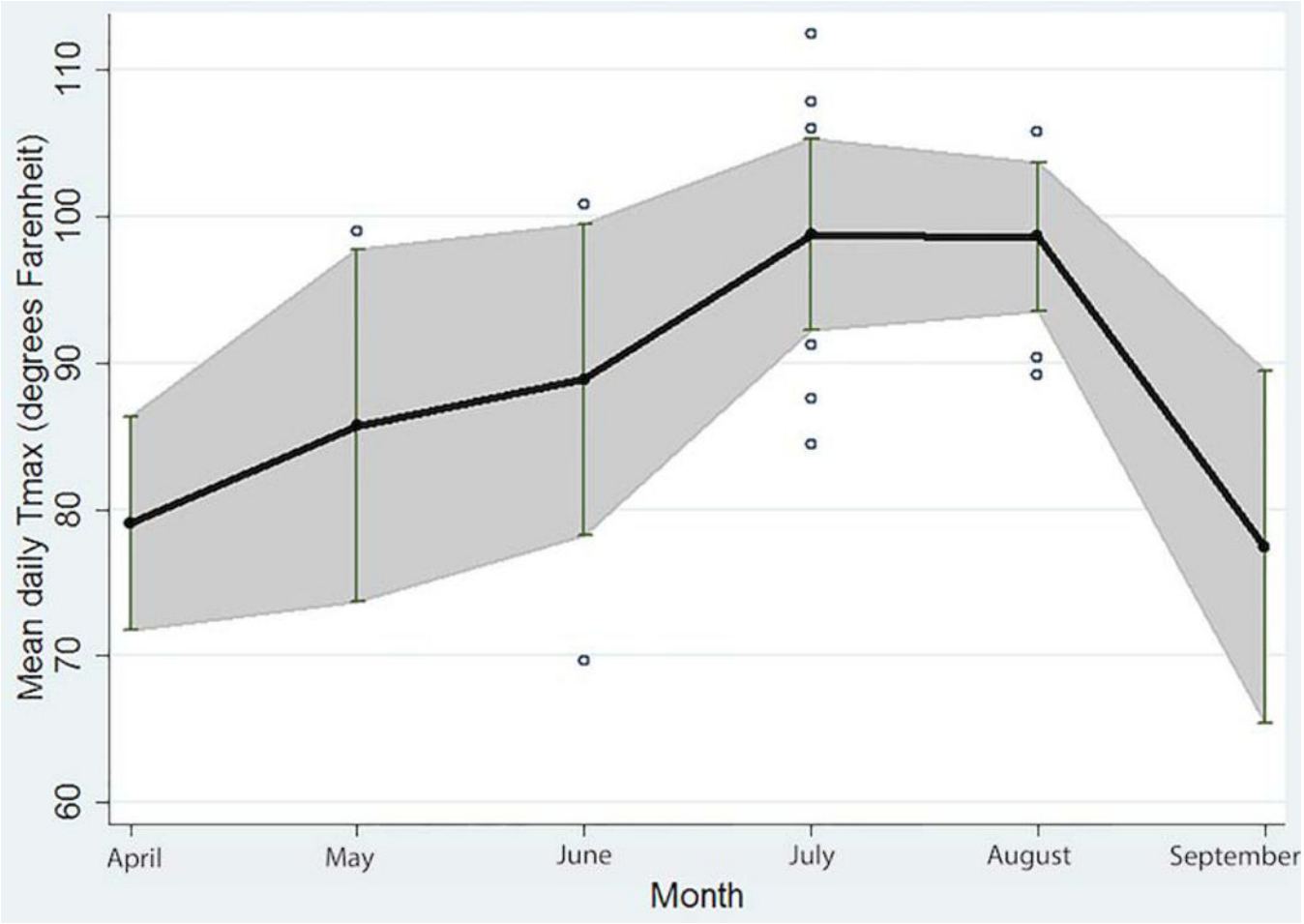

Figure 4. Mean daily maximum temperature for outdoor Washington State Fund agriculture and forestry workers' compensation heat-related illness (HRI) claims by month, 1995–2009

Black line: mean daily maximum temperature (T_{max}); vertical bars: +/- 1 standard deviation; open circles: T_{max} values greater or less than one standard deviation from the mean T_{max}. Fourteen outdoor claims missing temperature data.

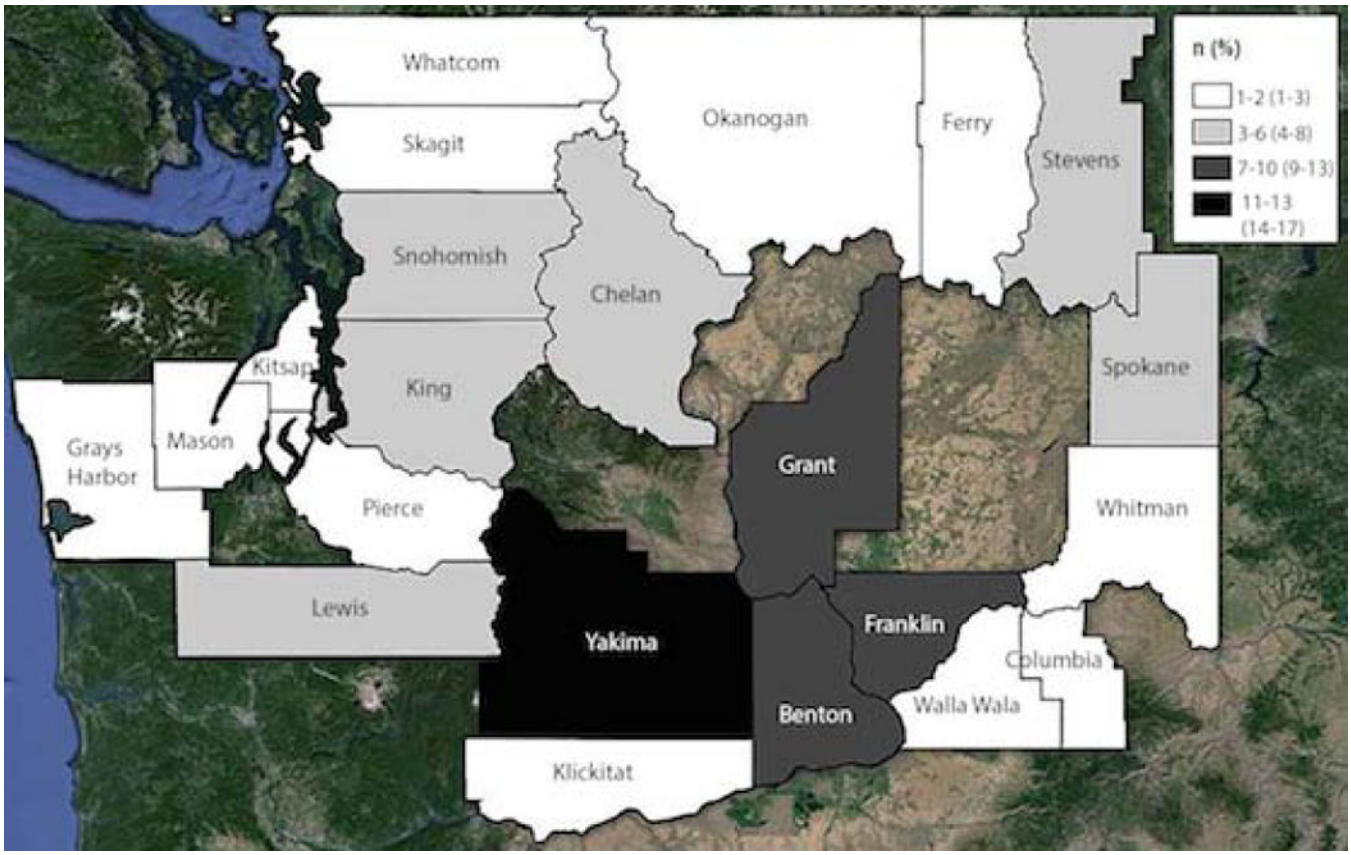

Figure 5. Geographical distribution of Washington State Fund agriculture and forestry workers' compensation heat-related illness (HRI) claims by county of injury, 1995–2009

Darker gray indicates a higher number of claims; six claims missing information on location of injury.

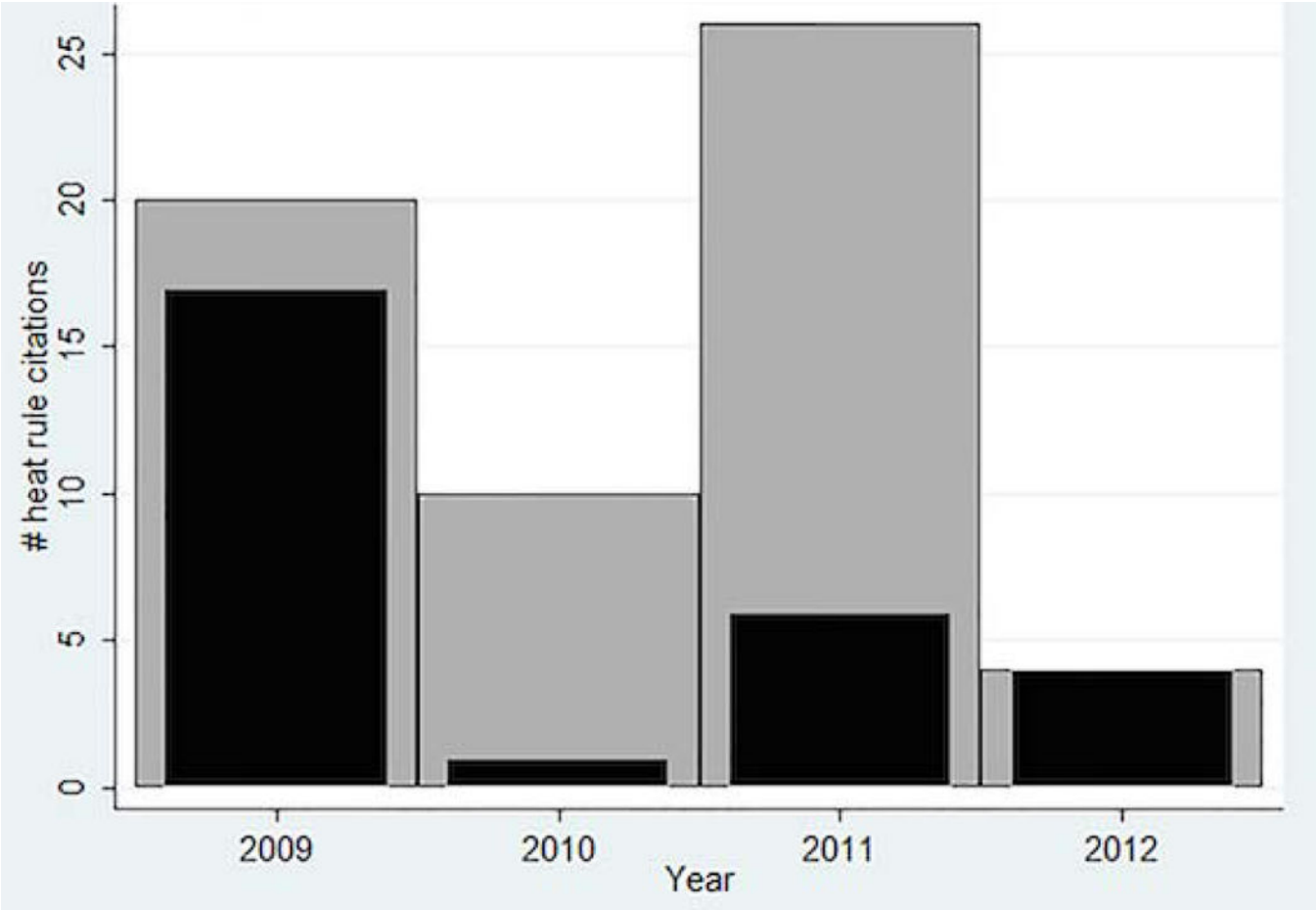

Figure 6. Washington Agriculture Heat Rule citations by year, 2009–2012

Gray bars: all violations; Black bars: number of unique businesses (by business location) with violations.

Table I

Industry/sector codes used to identify heat-related illness claims

Coding System	Code	Industry/Sector
	111	crop production
NAICS	112	animal production and aquaculture
	113	forestry and logging
and/or	114	fishing, hunting, and trapping
	115	support activities for agriculture and forestry
SIC	01-09	agriculture, forestry, and fishing
and/or	2411	logging
	4802	vegetable farms
	4803	orchards
	4804	egg and poultry farms
	4805	nurseries and shellfish farms
	4806	hand harvesting: berries, nuts, flowers
	4808	diversified field crops & cereal grains
	4809	greenhouses & mushroom farms
	4810	vegetable farms – hand harvest
Risk	4811	hop and mint farms
Class	4812	fish and shellfish hatcheries
	4813	vineyards
	7301	dairy farms
	7302	livestock farms and stables
	7307	tree farms
	5001	logging operations
	5004	forestry and timberland services
	5005	mechanized logging
	5006	forestry and timberland services machine operations
	7112	temporary help agricultural services
	7121	temporary help logging and aircraft services

North American Industrial Classification System (NAICS); Standard Industrial Classification (SIC)

Table II

International Classification of Diseases, Ninth Revision, Clinical Modification codes used to identify heat-related illness claims

ICD-9 Code	Description
705.1	Prickly heat
276	Hyperosmololality and/or hypernatremia
276.5	Volume depletion
276.5	Volume depletion, unspecified
276.51	Dehydration
276.52	Hypovolemia
584	Acute renal failure
584.9	Acute renal failure, unspecified
992	Effects of heat and light
992	Heat stroke and sunstroke
992.1	Heat syncope
992.2	Heat cramps
992.3	Heat exhaustion
992.3	Heat exhaustion, anhydrotic
992.4	Heat exhaustion due to salt depletion
992.5	Heat exhaustion, unspecified
992.6	Heat fatigue, transient
992.7	Heat edema
992.8	Other specified heat effects
992.9	Effects of heat and light

International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9)

Table III

Demographic, environmental, and work-related characteristics of accepted Washington State Fund workers' compensation claims for heat-related illness in agriculture and forestry, 1995–2009

	Crop Production & Support HRI Claims (*NAICS 111 or 1151;or WA risk class 4802, 4803, or 4813*)	**Forestry & Logging Support HRI Claims (*NAICS 113 or 1153*)**	**Landscape & Horticultural Services HRI Claims (*NAICS 56173 or SIC 078*)**	**All Agriculture & Forestry HRI Claims**	**All Agriculture & Forestry Claims**	**All State Fund Claims**
N total claims (n compensable; n non-compensable)	51 (4; 47)	14 (3; 11)	14 (1; 13)	84 (8; 76)	177,559 (46,479; 131,080)	2,010,006 (494,923; 1,515,083)
N third quarter claims (n compensable; n non-compensable)[1]	39 (2; 37)	11 (2; 9)	7 (0; 7)	61 (4; 57)	56,733 (14,436; 42,297)	553,677 (132,752; 420,925)
% Total agriculture and forestry HRI claims	61%	17%	17%	----	----	----
% Male	65%	93%	93%	76%	79%	71%
Median (interquartile range) age (years)[2]	33 (23, 47)	28 (20, 33)	27 (23, 46)	30 (23, 46)	33(25,43)	35(26,45)
N (%) HRI claims where HRI occurred during indoor work[3]	4 (8%)	0 (0%)	1 (7%)	7 (8%)	----	----
N (%) Outdoor claims occurring between May and September[3]	38 (93%)	10 (100%)	10 (100%)	60 (95%)	----	----
N (%) Outdoor claims occurring between June and August[3]	34 (83%)	8 (80%)	9 (90%)	53 (84%)	----	----
Mean T_{max} (interquartile range), outdoor claims (°F)[4]	95 (91, 101)	84 (69, 93)	95 (88, 99)	95 (89, 100)	----	----
Mean HI_{max} (interquartile range), outdoor claims (°F)[5]	100 (94, 106)	92 (90, 94)	95 (89, 98)	99 (90, 106)	----	----
Mean (SD) T_{max}-T_{min} outdoor claims (°F)[4]	43 (11)	31 (13)	36 (6)	42 (11)		
Top occupation by frequency of HRI claims, n (%)[6]	22 (43%) Farm workers & laborers	6 (43%) Other logging workers	5 (36%) Landscaping & grounds-keeping workers	21 (25%) Farm workers & laborers	----	----
Median length of employment (days)[7]	61	61	304	91	304	365

Heat-related illness (HRI); North American Industry Classification System (NAICS); Standard Industrial Classification (SIC)

[1] July, August, and September dates of injury

[2]Three values missing

[3]For fourteen claims, documentation was not detailed enough to distinguish indoor from outdoor

[4]Fourteen outdoor claims missing temperature data

[5]Eighteen outdoor claims could not be calculated (fourteen outdoor claims missing temperature data and four outdoor claims with a T_{max} < 80°F)

[6]Sixteen crop production & support observations missing/unclassified, 5 forestry & logging observations missing, 2 landscape & horticultural services observations missing

[7]Seventeen crop production & support observations missing, 5 forestry & logging observations missing, 4 landscape & horticultural services observations missing

Table IV

Time-loss and costs of Washington State Fund accepted workers' compensation claims for heat-related illness in agriculture and forestry, 1995–2009

	AF HRI claims	All AF claims	All SF claims
Mean cost per claim, total claims (accepted claims)	$3,502	$8,447	$8,674
Median cost per claim, total claims (accepted claims)	$654	$405	$416
Mean cost per claim, non-compensable claims (medical only)	$3,071	$655	$744
Median cost per claim, non-compensable claims (medical only)	$568	$287	$289
Mean cost per claim, claims requiring inpatient hospitalization or deaths	$24,533	$131,173	$145,323
Median cost per claim, claims requiring inpatient hospitalization or deaths	$6,536	$60,906	$73,800
Mean (range) time-loss days, claims requiring inpatient hospitalization	25 (0; 96)	265 (0; 5,937)	735 (0; 6,083)

Agriculture and Forestry (AF); Heat-related illness (HRI); State Fund (SF)

Table V

Clinical characteristics of Washington State Fund accepted workers' compensation claims for heat-related illness in agriculture and forestry, 1995–2009

Characteristic	n (%) or median (interquartile range)
HRI diagnosis group	
Heat rash (*ICD-9 705.1*)	1 (1%)
Heat syncope, heat cramps, heat exhaustion, heat edema, heat fatigue, other heat effects (*ICD-9 992, 992.1, 992.2, 992.3, 992.4, 992.5, 992.6, 992.7, 992.8, 992.9*)	61 (73%)
Dehydration, hyperosmololality/hypernatremia, hypovolemia/volume depletion, other (*ICD-9 276.0, 276.5, 276.50, 276.51, 276.52*)	19 (23%)
Heat stroke, acute renal failure (*ICD-9 992.0, 584, 584.9*)	13 (15%)
HRI severity	
Treated as outpatient	75 (89%)
Requiring inpatient hospitalization but not intensive care	3 (4%)
Requiring intensive care	5 (6%)
Died	1 (1%)
Medications, supplements, or alcohol/drugs as potential risk factors	13 (15%)
Concurrent medical conditions or previous HRI	16 (19%)
BMI (kg/m^2)[1]	26 (23, 29)

Body Mass Index (BMI); Heat-related illness (HRI); International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9)

[1]Thirty-one BMI values missing

Table VI

Characteristics of Washington Agriculture Heat Rule (Washington Administrative Code 296-307-097*) Citations, 2009–2012

Characteristic	n (%)
Citations by industry (NAICS)	
Nursery & Tree Production (111421)	17 (28%)
Other Non-citrus Fruit Farming (111339)	15 (25%)
Wineries (312130)	13 (22%)
All Other Miscellaneous Crop Farming (111998)	4 (7%)
Apple Orchards (111331)	3 (5%)
Other [Vegetable Farming 111219; Forest Nurseries & Gathering of Forest (113210); Landscaping Services (561730)]	3 (5%)
Postharvest Crop Activities (115114)	3 (5%)
Wheat Farming (111140)	2 (3%)
Violation type (Washington Administrative Code)	
Worker training (296-307-09760-1)	27 (45%)
Heat safety in accident prevention program (296-307-09730-1-1)	21 (35%)
Supervisor training (296-307-09760-2)	10 (17%)
Drinking water available (296-307-09740-1-1)	2 (3%)

North American Industry Classification System (NAICS)