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Background Little information exists describing the incidence of heat-related illness (HRI) among non-military working populations. An analysis of HRI cases utilizing workers’ compensation data has not been previously reported.

Methods We used both ICD-9 and ANSI Z16.2 codes with subsequent medical record review to identify accepted Washington State Fund workers’ compensation claims for HRI over the 11-year time period from 1995–2005.

Results There were 480 Washington workers’ compensation claims for HRI during the 11-year study period. NAICS industries with the highest workers’ compensation HRI average annual claims incidence rate were Fire Protection 80.8/100,000 FTE, Roofing Construction 59.0/100,000 FTE, and Highway, Bridge and Street Construction 44.8/100,000 FTE. HRI claims were associated with high outdoor ambient temperatures. Medical risk factors for HRI were present in some cases.

Conclusions HRI cases occur in employed populations. HRI rates vary by industry and are comparable to those previously published for the mining industry. Am. J. Ind. Med. 50:940–950, 2007. © 2007 Wiley-Liss, Inc.

KEY WORDS: heat-related illness; workers’ compensation; heat stroke; heat stress

INTRODUCTION

Normally the human body is very efficient at distributing heat within the body and losing excess heat to the surrounding environment. When conditions are such that the body retains more heat than it can release protective mechanisms can be overwhelmed, resulting in heat-related illness (HRI). HRI comprises a spectrum of disorders ranging from minimal health effects to heat stroke, and death. Types of HRI include: heat edema, heat cramps, heat syncope, heat exhaustion, and heat stroke. Less severe HRIs than heat stroke are usually self-limited and with appropriate care the victim fully recovers [Barrow and Clark, 1998]. Heat stroke has a high mortality rate and survivors may experience significant long term medical consequences [Department of the Army and Air Force, 2003]. There are two types of heat stroke; “classical” heat stroke and “exertional” heat stroke.

Classical heat stroke has been studied extensively [Naughton et al., 2002; MMWR, 2003]. Classical heat stroke results from extended exposures to hot environmental conditions that prevent heat dissipation. Risk factors for classical heat stroke include cardiovascular and respiratory disease, diabetes, obesity and the use of medications that reduce sweating, impair thermoregulation, and weaken cardiovascular responses. Individuals unable to care for themselves due to physical limitation, medical or psychological conditions may be unable to escape hot environments or take necessary steps for adequate cooling and thus are at increased risk. For example, classical heat stroke disproportionately affects the elderly because of the increased prevalence or severity of these risk factors.
Exertional heat stroke occurs sporadically in individuals with high metabolic output rates [Mehta and Jaswah, 2003]. Exertional heat stroke may occur under any weather conditions but is most prevalent during hot and humid weather [Bartley, 1977; ACGIH, 2006]. Exertional HRI results from high metabolic demands often in combination with hot environmental conditions. Research and field studies among US military personnel document increased exertional HRI risk associated with increased workload, high ambient temperatures and the inability to self regulate work rate in a training environment [Gardner and Kark, 2001; Department of the Army and Air Force, 2003].

The occurrence of exertional heat stroke and heat exhaustion has been reported among athletes [Wexler, 2002], in the mining industry [Donoghue and Bates, 2000; Donoghue, 2004], and in military populations [Bricknell, 1996; Kark et al., 1996]. With the exception of the US mining industry [Donoghue, 2004], the incidence of HRI among many US non-military, working populations has not been previously reported. The purpose of this study is to describe HRI among occupationally exposed populations in Washington State using workers’ compensation claims data and to identify known HRI risk factors in this population.

METHODS

The Washington State Department of Labor and Industries’ (L&I) State Fund (SF) is the exclusive provider of workers’ compensation insurance to all Washington employers, except those that are able to self-insure or are covered by alternative workers’ compensation systems (e.g., the federal government). Elective workers’ compensation coverage is available to the self-employed, employers of one household worker or other minor occupational groups exempt from mandatory coverage [Revised Code of Washington, 2005].

HRI Case Identification

L&I uses 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 worker’s compensation claim form [ANSI, 1969]. 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.

HRI claims were identified by a two step process. First, workers’ compensation claims were identified using a data systems definition (selected ICD-9 codes and ANSI-Z16.2 codes). Subsequently, identified claims underwent physician review to determine if the claim was filed for a heat related illness.

On January 29, 2007, we identified all accepted SF workers’ compensation claims with dates of injury between January 1, 1995 and December 31, 2005 with any one of the following ICD-9 codes: 992.0—Heat stroke and sunstroke; 992.1—Heat syncope; 992.2—Heat cramps; 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; or 992.9—Effects of heat and light, unspecified; and/or an ANSI Z16.2 type code 151 (Contact with general heat—atmosphere or environment). This study was restricted to SF claims because ICD-9 codes are not available for self-insured claims.

For claims meeting the HRI data systems definition, we extracted the worker, physician and employer electronic claim text fields describing the injury on the Report of Industrial Injury and Occupational Disease (RIIOD) form. The RIIOD form filing initiates a workers’ compensation claim in Washington State and requires completion by both the worker and physician. Information on the RIIOD is transcribed verbatim into L&I’s electronic databases. Two physicians independently reviewed the RIIOD electronic claim text fields to determine whether the claim was consistent with an HRI (e.g., the words ‘heat exhaustion’ or ‘heat stroke’ appeared in the claim text). If the information in the electronic claim text field was insufficient or absent, the medical record for the claim was reviewed. 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 consensus determination was made by reviewing the claim text fields and the medical records.

Of the 946 claims identified using the HRI ICD-9 codes or ANSI Z16.2 type code 151, 492 were HRI claims after medical review of the electronic claim text fields and medical records. If the worker had a SF HRI claim but the employer’s physical business location was determined to be outside of Washington State the claims were excluded from further analysis (12 claims). Therefore, by the above case identification procedures 480 HRI claims occurred during our study period.

Of the 946 claims identified, 454 claims satisfied the data systems definition as HRI claims but on physician review of the electronic claim text fields were not HRI cases. Of these 454 ‘false positive’ claims, 34 were assigned the ANSI Z16.2 type code 151 (Contact with general heat—atmosphere or environment). Of the 34, 23 were burns resulting from either contact with or exposure to hot air, gases, vapors, or liquids. The coding of these cases is within the standards of the ANSI Z16.2 type code 151. The remaining 11 cases appear to have been miscoded with inappropriate ANSI z16.2 type codes.
Characteristics of HRI Claims

Data obtained for each claim included the unique claim identification number, the claimant’s date of birth, the date and hour of injury, the ANSI Z16.2 codes, the assigned North American Industrial Classification System (NAICS) code for the employers’ account and physical business location, the claim status code, the claimant’s occupation code according to the 2000 Standard Occupational Classification (SOC) system, the cost of the claim, and the duration of the workers’ employment with the employer of record. For comparison purposes, similar data, if available, were collected for all accepted SF 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. 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 4 or more days of time loss from work. Both compensable and non-compensable claims were included in the study.

Employer accounts are assigned a NAICS code based on their principal economic activity. The North American Industrial Classification System is a hierarchical six digit industrial classification system [OMB, 2002]. Each particular industry is assigned a six digit code where the first two digits of the code designate the sector, the first three digits designate the subsector, the first four digits designate the industry group, the first five digits designates the NAICS industry and the sixth digit provides country specific information. Thus, an employer assigned NAICS industry 238160—Roofing Contractors is also part of industry group 238—Specialty Trade Contractors, which is part of subsector 238-Specialty Trade Contractors, which is part of industry sector 23 Construction. The zero as the sixth digit for the Roofing Industry indicates that the NAICS industry and the U.S. Industry are the same.

Each claim is assigned a SOC code to describe the worker’s occupation. The Standard Occupational Classification System, 2000 is a six digit hierarchical classification system [OMB, 2000]. Each occupation is assigned a six digit detailed occupational code. The first two digits of a SOC code represent the major occupational group, the first three digits represent the minor occupational group, the first five digits represent the broad occupation and the sixth digit represents the detailed occupation. Thus, a workers’ detailed occupation assigned as a Firefighter 33–2011 is equivalent to the broad occupation of 33–201(0), which is a subset of the minor occupational group 33–2000 Firefighting and Prevention Workers, which is a subset of the major occupational group 33-0000 Protective Service Occupations.

For the claims meeting the above HRI case definition, we then reviewed the workers’ compensation claim medical and administrative records to determine if the heat exposure occurred in an indoor work environment and whether there was the presence of a potential risk factor for HRI related to medication use and/or a concurrent medical condition [Barrow and Clark, 1998]. An indoor work environment was considered to be a work area enclosed by a roof, floor and four walls (e.g., a shed with only three walls or a truck cab was considered to be an outdoor work environment). Approximately 50% of claims were not coded for occupation with the current SOC 2000 system and these claims were manually recoded.

Historical weather data was obtained from the National Atmospheric and Oceanographic Administration’s (NOAA) National Climatic Data Center (NCDC). Each of Washington’s 39 counties was assigned to 1 of 14 weather stations with historical weather data available throughout the study period. An approximation of the temperature associated with the HRI claimants’ worksite was determined by using the county of the employer’s physical business location. The maximum daily temperature (T max) for the date of injury and the 3 days preceding the injury was obtained by matching the county of the employer’s business location to the county’s assigned referent NCDC weather station.

A day with more than one HRI claim defines a ‘cluster’ of HRI claims. To assign a T max for days in which a cluster occurred, the T max associated with each of the day’s HRI claims business locations were combined and averaged.

Employers within the Washington SF are required to report the cumulative number of hours worked by their employees on a quarterly basis. Time periods for the quarterly reporting were first quarter, January–March; second quarter, April–June; third quarter, July–September; and, fourth quarter, October–December. Employer hours were
aggregated by account and assigned the employer’s North American Industrial Classification System (NAICS) code. Claim incidence rates were determined by assuming that an FTE is equivalent to 2000 work hours. All descriptive analyses were performed with Microsoft Office Excel 2003, SPSS 14.0 Version for Windows and SAS Version 9.1.

RESULTS

There were 480 accepted SF HRI claims from January 1, 1995 to December 31, 2005 in Washington State. A total of approximately 1.56 million accepted SF claims occurred during the study period. Of the 480 HRI claims, 442 (92.1%) were classified as ‘non-compensable’ (medical-only), and 38 (7.9%) were considered ‘compensable’ (involves ≥4 lost workdays, a permanent partial disability award, were kept-on-salary by the employer or resulted in a fatality). Approximately 24% of all Washington State workers’ compensation state fund claims are compensable.

HRI claim costs and HRI claimants’ gender and age are compared to those claim characteristics for all SF claims in Table I. The average age of an HRI claimant was 35 years old and the median age was 34 years. The proportion of HRI claimants under 25 years old was significantly more than the proportion of all SF claimants under 25 years old ($P < 0.005$).

The average of age of the worker with an HRI compensable claim was 41 years which is comparable to the average age for all SF compensable claimants at 39 years old. Workers over 54 years old accounted for 18.9% of HRI claims; however this proportion was not significantly different from the proportion of all SF claimants over 54 years of age (11.3%).

The cumulative cost for the 11-year period for all HRI claims was $985,196. The range of claim costs for all accepted SF HRI claims was from $0 to $216,449. The range of non-compensable claim costs for HRI claims was from $0 to $8,200. The range of compensable claim costs for HRI claims was $39 to $216,449. Thirty-four claims received time loss compensation. Time loss days paid by the SF workers’ compensation system ranged from 1 to 659 days.

Industry and Occupation

HRI claim incidence rates by industry sector (two digit NAICS) were highest in Construction (NAICS 23) at 12.1 per 100,000 FTE, Public Administration (NAICS 92) at 12.0 per 100,000 FTE, Agriculture, Forestry, Fishing and Hunting (NAICS 11) at 5.2 per 100,000 FTE, and Administrative and Support and Waste Management and Remediation Services (NAICS 32) at 3.9 per 100,000 FTE (Table IIa). The distribution of HRI claims differs from that of all SF accepted claims with an excess proportion of claims occurring mostly in Construction, and Public Administration.

Of the 480 claims, 377 (78.5%) occurred as a result of work outdoors. The Manufacturing and Accommodation and

<table>
<thead>
<tr>
<th>Table I. Characteristics of Washington State Accepted State Fund (SF) Claims for Heat-Related Illness (HRI) Compared With All Washington SF Claims, 1995–2005</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HRI claims and all state fund (SF) claims, Washington State, 1995–2005</strong></td>
</tr>
<tr>
<td><strong>% male</strong></td>
</tr>
<tr>
<td><strong>% age group</strong></td>
</tr>
<tr>
<td>14–17</td>
</tr>
<tr>
<td>18–24</td>
</tr>
<tr>
<td>25–34</td>
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<tr>
<td>35–44</td>
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<tr>
<td>45–54</td>
</tr>
<tr>
<td>55–64</td>
</tr>
<tr>
<td>65+</td>
</tr>
</tbody>
</table>

Accepted claims: n = 480 n = 1.56 million

Average cost per claim $1,864 $6,311

Median cost $537 $345

Non-compensable claims only:

Average cost per non-compensable claim $732 $638

Median cost $515 $251

Compensable claims only

Average cost per compensable claim $15,041 $24,330

Median cost $1,916 $4,771

Time loss claims n = 34 n = 286,500

Average time loss days per claim 46 193

Median time loss days 6 36

* A compensable claim includes claims with payment for time lost from work, an injured worker kept on salary, an injured worker receiving a disability award or a fatality.

Food Services sectors were the only NAICS industry sectors where the majority of HRI claims occurred from indoor work. Within Manufacturing, 80% (35/44) of claims occurred from work indoors; 14 of which were in the Primary Metal Manufacturing subsector—NAICS 331.

In Construction (NAICS 23), 16/159 (10.1%) claims were compensable, while in Agriculture, Forestry and Fishing (NAICS 11), 7/33 (21.2%) claims were compensable. None of the 85 claims in the Public Administration Sector were compensable.

NAICS Industries (six digit NAICS) with the highest annual claim incidence rates include Fire Protection (NAICS 922160) at 80.8 per 100,000 FTE, Roofing Construction (NAICS 922160) 59.0 per 100,000 FTE and Highway, Street and Bridge Construction (NAICS 237310) at 44.8 per 100,000 FTE (Table IIb). In Roofing Construction, 18.5% (5/27) of the claims were compensable.

Almost all claims in the highest risk industries occurred from exposures to an outdoor work environment. While seasonal workers are not identified in L&I databases, the HRI
annual claims incidence rate in the Temporary Help Services Industry (NAICS 561320) was 4.6 per 100,000 FTE.

HRI claim rates by NAICS industry sector (2-digit) and NAICS industries (6-digit) for the third quarter, the reporting period matching the greatest level of exposure to elevated environmental temperatures, far exceeded the annual HRI claim incidence rate. The highest third quarter rates by NAICS industry were for Roofing Construction (NAICS 238160) at 161.2 per 100,000 FTE and for Fire Protection (NAICS 922160) at 158.8 per 100,000 FTE.

The distribution of the Standard Occupation Classification 2000 codes for SF HRI claims is presented in Table III. Most occupations had the majority of their HRI claims as a result of exposure to heat in the outdoor environment. The exceptions were Furnace, Kiln, Oven, Drier, and Kettle Operations and Tenders (SOC 51905), Machine Tool Cutting Setters, Operators, Tenders, Metal and Plastic (SOC 51403), Cooks (SOC 35201), Miscellaneous Production Workers (SOC 51919), and Building Cleaning Workers (SOC 37201). Compensable claims were most common in Roofers (SOC 47218) and Miscellaneous Agricultural workers (SOC 45209) where 5 of 23 (21.7%), and 4 of 20 (20%) were compensable, respectively.

**Temporal Distribution of Claims**

The average number of HRI claims per year was 44. The annual number of claims ranged from 28 to 73. Annual SF HRI claims incidence rates ranged from 1.9 to 5.1 per 100,000 FTE. The monthly distribution of HRI claims over the study period and whether the work location for the claimant was outdoors or indoors are presented in Figure 1. From May through September, 456 (95.0%) HRI claims occurred. However, 82.7% of the HRI claims occurred during the 3 months of June, July, and August. Ten of the 24 claims that occurred between October and April were from workers in indoor environments.

HRI claims occurred on 308 days during the study period. Eighty-eight days during the study period had multiple HRI claims, a cluster, and represent 260 claims or 54.2% of all claims. Eighty-three of the 88 days with a cluster of HRI claims were in June through August. The remaining four HRI clusters occurred in May and September. The number of HRI claims in a cluster ranged from 2 to 15 claims. There were 49 clusters of two claims, 24 clusters of three claims, six clusters of four claims, four clusters of five claims, and one cluster each of 6, 7, 8, 10, and 15 claims. The largest clusters of HRI claims occurred on sequential days; 7/27–28/1998 (10 and 15 claims, respectively) and 7/11–12/2002 (7 and 6 claims, respectively). Both indoor and outdoor claims were part of a cluster. Fifty-five of the 103 (53.4%) indoor claims and 205 of the 377 (54.4%) outdoor claims were part of a cluster.

There were 415 individual employer accounts with an accepted HRI claim during the study period. The number of claims per employer account ranged from 1 to 8. Forty employer accounts had more than one HRI claim during the study period. Seventeen of these forty accounts with multiple HRI claims were in the Public Administration (NAICS 92).
Only two employer accounts had multiple HRI claims in a single day. Hour of injury was determined for 399 of the 480 claims. Of the 399 claims, 358 (89.7%) occurred between 10 am and 6 pm and 80.4% were from heat exposure outdoors. There were 41 claims with hour of injury between 7 pm and 9 am and 24 (58.5%) occurred in the outdoor environment (Fig. 2). Eastern Washington is known for hot, dry summers and is geographically separated from Western Washington by the Cascade Mountain range. Approximately 24% of all SF workers' compensation claims occur in Eastern Washington but the area accounted for 220 (45.6%) of the HRI claims. Average maximum daily temperatures for SF HRI claims from 1997 to 2005 are presented in Table IV. The daily Tmax interquartile range for all HRI claims was 77–94 °F (i.e., 25% of the HRI claims occurred below 77 °F, 25% occurred with temperatures above 94 °F and the remaining 50%, the interquartile range, were between these two temperatures). The average maximum temperature for the 308 days in which an HRI claim occurred was 80.8 °F.

To assess if there is a difference in maximum daily temperature on days with multiple claims compared to days with a single HRI claim, we excluded HRI claims from firefighters (SOC Occupation = 33201) and HRI claims which occurred indoors. The geographic distribution of claims, Eastern Washington compared to Western Washington, on days with multiple HRI claims compared to days with a single HRI claims did not significantly differ. However, there was a statistically significant difference (P < 0.001) between the average Tmax for days in which a single claim occurred (Tmax average 80.4 °F) and the average Tmax for days with multiple HRI claims (Tmax avg. 88.5 °F).

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Industry name</th>
<th>% All SF claims N = 1.56 million</th>
<th>HRI claims (%)</th>
<th>HRI claim rateb</th>
<th># outdoor claims</th>
<th>HRI third qtr. claims</th>
<th>HRI third qtr. claim rateb</th>
</tr>
</thead>
<tbody>
<tr>
<td>238160</td>
<td>Roofing construction</td>
<td>1.1</td>
<td>27 (5.6)</td>
<td>59.0</td>
<td>27</td>
<td>21 (60)</td>
<td>1612</td>
</tr>
<tr>
<td>922160</td>
<td>Fire protection</td>
<td>0.2</td>
<td>22 (4.6)</td>
<td>80.8</td>
<td>20</td>
<td>11 (3.1)</td>
<td>158.8</td>
</tr>
<tr>
<td>237310</td>
<td>Highway, street and bridge construction</td>
<td>0.5</td>
<td>21 (4.4)</td>
<td>44.8</td>
<td>21</td>
<td>16 (4.6)</td>
<td>105.6</td>
</tr>
<tr>
<td>924120</td>
<td>Administration of conservation programs</td>
<td>0.4</td>
<td>19 (4.0)</td>
<td>34.3</td>
<td>19</td>
<td>12 (3.4)</td>
<td>74.8</td>
</tr>
<tr>
<td>238910</td>
<td>Site preparation construction</td>
<td>0.5</td>
<td>18 (3.8)</td>
<td>35.9</td>
<td>18</td>
<td>16 (4.6)</td>
<td>106.5</td>
</tr>
<tr>
<td>236115</td>
<td>New single family housing construction</td>
<td>2.9</td>
<td>16 (3.3)</td>
<td>8.9</td>
<td>16</td>
<td>13 (3.7)</td>
<td>27.1</td>
</tr>
<tr>
<td>238110</td>
<td>Poured concrete foundation and structural construction</td>
<td>0.6</td>
<td>16 (3.3)</td>
<td>35.9</td>
<td>16</td>
<td>13 (3.7)</td>
<td>102.6</td>
</tr>
</tbody>
</table>

TABLE IIb. Washington State Accepted State Fund Workers' Compensation Annual and Third Quartera Claims Rate for Heat-related Illness (HRI) by North American Industrial Classification System (NAICS) Industry (Six Digit Code) With > 5 claims for 1995–2005

aThe third quarter comprises July, August, and September. bRate per 100,000 FTE.
When reviewing the daily $T_{\text{max}}$ for the 3 days preceding the HRI claim, 200 of the 480 HRI claims (41.7%) were noted to have a 10 degree increase in the $T_{\text{max}}$. Of these 200 claims, 135 (67.5%) were associated with a cluster. Of the 280 claims not associated with a 10 degree increase in the $T_{\text{max}}$, only 125 (44.6%) were associated with a cluster of claims.

**TABLE III.** Distribution by Occupation Using Standard Occupation Classification 2000 (SOC) for Accepted Washington State Fund Workers’ Compensation Heat Related Illness Claims, 1995—2005

<table>
<thead>
<tr>
<th>SOC codes</th>
<th>Code description</th>
<th># claims (%)</th>
<th># outdoor claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>47206</td>
<td>Construction laborers</td>
<td>41 (8.5)</td>
<td>39</td>
</tr>
<tr>
<td>33201</td>
<td>Fire fighters</td>
<td>39 (8.2)</td>
<td>37</td>
</tr>
<tr>
<td>53706</td>
<td>Laborers and material movers, hand</td>
<td>35 (7.3)</td>
<td>27</td>
</tr>
<tr>
<td>47203</td>
<td>Carpenters</td>
<td>23 (4.8)</td>
<td>23</td>
</tr>
<tr>
<td>47218</td>
<td>Roofers</td>
<td>23 (4.8)</td>
<td>23</td>
</tr>
<tr>
<td>53303</td>
<td>Driver/sales workers and truck drivers</td>
<td>21 (4.4)</td>
<td>20</td>
</tr>
<tr>
<td>45209</td>
<td>Miscellaneous agricultural workers</td>
<td>20 (4.2)</td>
<td>20</td>
</tr>
<tr>
<td>37301</td>
<td>Grounds maintenance workers</td>
<td>13 (2.7)</td>
<td>13</td>
</tr>
<tr>
<td>49909</td>
<td>Miscellaneous installation, maintenance, and repair workers</td>
<td>12 (2.5)</td>
<td>11</td>
</tr>
<tr>
<td>51905</td>
<td>Furnace, kiln, oven, drier, and kettle operations and tenders</td>
<td>10 (2.1)</td>
<td>0</td>
</tr>
<tr>
<td>33903</td>
<td>Security guards and gaming surveillance officers</td>
<td>8 (1.7)</td>
<td>8</td>
</tr>
<tr>
<td>33909</td>
<td>Miscellaneous protective service workers</td>
<td>8 (1.7)</td>
<td>8</td>
</tr>
<tr>
<td>37201</td>
<td>Building cleaning workers</td>
<td>8 (1.7)</td>
<td>3</td>
</tr>
<tr>
<td>51403</td>
<td>Machine tool cutting setters, operators, tenders, metal and plastic</td>
<td>8 (1.7)</td>
<td>0</td>
</tr>
<tr>
<td>35201</td>
<td>Cooks</td>
<td>7 (1.5)</td>
<td>1</td>
</tr>
<tr>
<td>51919</td>
<td>Miscellaneous production workers</td>
<td>7 (1.5)</td>
<td>2</td>
</tr>
<tr>
<td>99999</td>
<td>Non-classifiable</td>
<td>7 (1.5)</td>
<td>6</td>
</tr>
<tr>
<td>47200</td>
<td>Construction trades workers</td>
<td>6 (1.3)</td>
<td>6</td>
</tr>
<tr>
<td>47211</td>
<td>Electricians</td>
<td>6 (1.3)</td>
<td>3</td>
</tr>
<tr>
<td>51412</td>
<td>Welding, soldering, and brazing workers</td>
<td>6 (1.3)</td>
<td>4</td>
</tr>
<tr>
<td>All other occupations</td>
<td>172 (35.8)</td>
<td>120</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 1.** The distribution by month of injury for Washington State Fund workers’ compensation heat-related illness claims, 1995—2005 ($n = 480$). (□ outdoor; ■ indoor).

**Risk Factors for HRI**

**Medication use and co-morbid medical conditions**

Review of the medical information from each HRI claim assessed whether medication use by the claimant or a
concurrent medical condition could have placed the worker at increased risk for the development of HRI. Due to the non-systematic collection of medical conditions, medication, alcohol, and drug use within the SF workers’ compensation medical record, our data represents a minimum estimate of the presence of medication use or the co-morbid medical conditions in HRI claimants.

There were 106 (22.1%) HRI claims where medication use or a medical condition may have played a contributing role to the development of the HRI. Commonly used medications noted were hydrochlorothiazide diuretics, beta-blockers, antihistamines, and psychiatric medications. Common medical conditions identified included cardiovascular disease, psychiatric conditions, concurrent infection, possible illicit drug use and alcohol use either daily or during the days preceding the HRI claim. Twenty workers reported a history of a previous HRI or treated dehydration but no HRI claimant had filed multiple HRI claims during the study period.

**Acclimatization**

Variation in environmental temperatures on the incidence of HRI is supported by the grouping of HRI claims during the summer months (Fig. 1). Another group of workers potentially at risk are those immediately beginning employment in a work environment requiring significant physical exertion. This group of workers may be poorly adjusted to the workplace ambient temperature and/or the metabolic heat generation associated with increased physical work activities. Of the 480 HRI claims, 308 had information on the duration of employment. Of the 308, 43 (14.0%) claimants reported employment of 1 week or less. For all SF claims, the proportion of claimants reporting employment of 1 week or less before their day of injury was 3.3%.

**DISCUSSION**

We report workers’ compensation claims incidence rates for HRI in Washington State. Industries with the highest claim rates reflect those with increased outdoor work exposure. Claims occurring in an indoor environment also were common during the summer months, suggesting a relationship with outside temperatures. There is little available literature regarding diverse occupationally exposed non-military populations to compare with this descriptive HRI study.

**HRI Incidence Rate**

Occupational HRI incidence rates based on Washington State workers’ compensation claims during the entire 11-year study period (1995–2005) were highest among these NAICS industries: Fire Protection, 80.8 claims per 100,000 FTE, Roofing Construction, 59.0 claims per 100,000 FTE, and Highway Bridge and Street Construction, 44.8 claims per 100,000 FTE.

An occupational study of US mining operations over a 19-year period (1983 through 2001) reported HRI incidence

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**TABLE IV. Maximum Daily Temperature (T\text{max}) by Date of Injury for HRI Workers’ Compensation State Fund Claims, Washington State, 1995–2005 (n = 480)**

<table>
<thead>
<tr>
<th></th>
<th>Mean ( T\text{max} (\degree F) )</th>
<th>Median ( T\text{max} (\degree F) )</th>
<th>( T\text{max range} (\degree F) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>All HRI claims</td>
<td>84.1</td>
<td>85</td>
<td>44–108</td>
</tr>
<tr>
<td>Outdoor HRI claims (n = 377)</td>
<td>84.9</td>
<td>85</td>
<td>44–108</td>
</tr>
<tr>
<td>Indoor HRI claims (n = 103)</td>
<td>81.3</td>
<td>84</td>
<td>45–106</td>
</tr>
</tbody>
</table>
rates consistent with our study [Donoghue, 2004]. HRI incidence rates for underground mining ranged from 0.55 cases per 100,000 FTE for coal to 33.6 cases per 100,000 FTE for metal. Surface mining HRI incidence rates ranged from 5.3 cases per 100,000 FTE for coal to 12.9 cases per 100,000 FTE for stone. HRI incidence rates among mills and preparation plants ranged from 5.1 cases per 100,000 FTE for coal to 83.4 cases per 100,000 FTE for stone.

Hospital and clinic recorded HRI incidence from 1982 to 1991 among US Marine recruits undergoing basic training at Parris Island, South Carolina was 2,686 cases per 100,000 person years [Kark et al., 1996]. Our HRI incidence case rate is far less than the incidence case rate reported among military recruits, which is likely due to the extraordinary physical demands of basic training of military recruits and the heightened awareness and reporting of HRI in military settings.

With the exception of heat stroke, most HRIs are self-limiting and thus abate without medical intervention, increasing the probability that many cases of HRI in non-military work settings may not be recognized or reported.

**HRI Risk Factors**

**Seasonal increases in daily temperature**

The most apparent risk factor for increased Washington incidence of HRI is higher outdoor temperatures experienced from May through September. We found that 95% of total HRI claims occurred during these months. Similar results are apparent for other occupational and military studies. In US mining 91.5% of total cases occurred during these months [Donoghue, 2004] and 88% of the HRI cases among US Marine recruits at the Parris Island military base occurred during this time period [Kark et al., 1996]. July is the month associated with the highest incidence rates for all three studies.

The significantly increased average daily $T_{\text{max}}$ on days with multiple HRI claims compared to those with a single HRI claim, when excluding indoor claims and those claims in which there is likely an non-environmental external source of heat (firefighter claims), suggests a dose-response effect of environmental ambient temperature on HRI claims incidence.

**Hour of injury**

Our finding that the hottest parts of the day, 10 am to 6 pm, coincided with the greatest number of HRI claims differs from the exertional HRI cases reported among some military recruit training populations. Kark et al. [1996] found the greatest number of cases occurring between 7 am and 9 am, under relatively low ambient temperatures during physical training sessions. Observations also varied among those investigating the incidence of exertional heat stroke among military populations. Bartley [1977] found that incidence of exertional heat stroke occurred at various times of day under all types of weather conditions, while O’Donnell [1975] found a higher incidence during the hotter parts of the day or concurrently with or immediately after strenuous exercise. These data suggest that high exertion levels, alone or in conjunction with high ambient temperatures, increase the risk for HRI. Additional information tracking the workload of the HRI victim may clarify the disparities reported by hour of injury between the military studies and the occupational HRI cases observed in our study.

**Acclimatization**

Acclimatization is a series of physiologic changes or accommodations made by the body in response to repeated heat stress exposures while conducting work. Acclimatized individuals have an increased tolerance to heat stress because they are physiologically better able to distribute heat within their bodies and lose excess heat to the environment more efficiently [ACGIH, 2006]. Lack of acclimatization is a well-known risk factor for HRI [Gardner et al., 1996; Epstein et al., 1999].

In this study ‘length of time employed’ data, as available, is used as an index of acclimatization. Lack of acclimatization to increased work load with increased ambient temperatures may have been a factor in 14% of the occupational HRI cases. Our data indicates HRI claims occurring within 1 week of employment occurred more than four times as frequently as workers suffering injuries from all causes within that time period. However, the strength of this measure is limited in that only 65% of HRI claims had length of employment reported. Also, lack of acclimatization, regardless of the length of employment, due to seasonal change, a heat wave or from a sudden increase in exertion are not captured by ‘length of time employed.’ Review of the daily $T_{\text{max}}$ on the days preceding the HRI claims suggest significant increases in daily $T_{\text{max}}$ in the days preceding the date of injury; approximately 42% of HRI claims had an increase of the daily $T_{\text{max}}$ of 10 degrees Fahrenheit. Furthermore, cases associated with a cluster of claims were more likely associated with variation in temperature during the days preceding the injury. Thus, poor acclimatization may play a larger role in occupational HRI cases than can be measured using the data available. Developing a means to systematically capture the workload and more detailed environmental conditions will further elucidate the role of acclimatization in exertional HRI cases in a non-military work setting.

**Co-morbid risk factors for HRI**

Medical conditions or use of medications illicit drugs or alcohol was present in 22.1% of claims. Exertional HRI risk
factors among military recruit populations include infectious disease, sleep loss, generalized fatigue, sudden increase in physical training, prolonged heat stress exposure [Armstrong et al., 1990], obesity, lack of physical fitness, dehydration [Bartley, 1977], and, significant heat exposure the day prior to injury [Kark et al., 1996]. Military populations are likely to be at relatively low risk for co-morbid HRI medical conditions such as cardiovascular disease and diabetes due to both the reduced incidence of these conditions among younger populations and medical selection/exclusion criteria for military recruits.

Awareness of the medical conditions, medications or personal risk factors that place an individual at risk for HRI should be a required component of a training program. Additional systematic data collection of the prevalence of medication use in HRI cases and a referent population may provide further information on the importance of these risk factors in a non-military population.

**Study Limitations**

The limitations to this descriptive study include the likely under reporting of HRI to the workers’ compensation system and the under recognition of HRI by workers, employers and the medical community. There is a possibility of misclassification of HRI workers’ compensation claims to other diagnosis if the injury was poorly described on the worker’s compensation claim form [Dinman and Horvath, 1984]. It cannot be determined if concurrent medical conditions and medication use played a role in the workers development of an HRI or were coincidental findings. Washington workers’ compensation data used in this study were restricted to the SF employers, thus excluding 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). These exclusions likely lead to an underestimate of the number of HRI claims in Washington State for the study period.

The methods used to assign ambient temperatures to individual claimant exposures can be regarded only as a crude approximation; many of the worksites are not located at the employer’s physical business location and the historical temperature data is from the referent city closest to that business location. The duration of work in hot temperatures, the humidity on the day of injury, wind speeds, and other factors (e.g., sun exposure, cloud cover) on the day of injury are not accounted for in this study. Differential information bias may explain the increased average $T_{max}$ on days where multiple HRI claims occurred relative single HRI claim days. In other words, on hot days health care providers may more readily recognize and diagnose HRI.

**HRI Prevention**

The current study and work of others indicate that increased summer time outdoor temperatures are associated with higher exertional HRI incidence rates. Consequently, education, planning, and resources aimed at prevention should be in place prior to significant seasonal exposures.

The effects of interventions to control heat exposures and prevent HRI have been reported from the US military. Stonehill and Keil [1961] reported the results of an intervention based on curtailing vigorous outdoor activity at Lackland Air Force Base in Texas when Wet Bulb Globe Temperature (WBGT) index measurements reached 88°F. Exertional heat stroke cases were reduced from 39, the year prior to the intervention to two heat stroke cases during the year the intervention was introduced and three cases the following year. Kerstein et al. [1986] compared the incidence of exertional HRI between a study group and a control group of infantry reservists undergoing training after the institution of administrative controls to prevent HRI. The intervention included a short training on heat casualty prevention, implementation of work/rest cycles and scheduled water intake, a special briefing for the group’s Commanding Officers and the use of a WBGT metering device. The incidence of heat casualties, defined as an individual being non-functional for 1 hr or more, among the study group was one-half that of the control group.

These intervention studies suggest the value of anticipating high temperatures, assessing environmental conditions, and implementing preventative changes that reduce metabolic heat loading when necessary. Current military HRI prevention practices include considerations such as heat illness recognition and prevention training, WBGT based environmental assessment, guidelines for work/rest cycles, and guidelines for water intake [Department of the Army and Air Force, 2003].

We found HRI risk factors including co-morbid medical conditions, the use of medications, illicit drugs or alcohol, and lack of acclimatization present in some occupationally exposed HRI cases. Military HRI cases also point to the presence of personal risk factors supporting the belief that personal risk factors play a role in the development and severity of HRI [ACGIH, 2006]. These data suggest that prevention measures include accommodation for un-acclimatized workers, plans and procedures for decreasing operational and personal risk factors, and employee training. The training should include information on HRI risk factors and on the prevention, identification and treatment of HRI.

Optimally, employers should have a comprehensive heat stress prevention program that identifies heat stress hazards, assesses the hazards in terms of severity and probability, implements the appropriate controls, and continuously evaluates the effectiveness of these controls. Thus, components of an employer’s written comprehensive heat illness
prevention program will include engineering controls, appropriate work practices for environmental conditions, employee training, personal protective equipment, and preventive medical practices [Department of the Army and Air Force, 2003; ACGIH, 2006].

CONCLUSIONS

The most apparent association for exertional HRI is exposure to increased ambient temperatures during summer months. Personal risk factors including co-morbid medical conditions, medications, illicit drug and alcohol use and limited acclimatization were present in some cases. Incorporation of prevention programs into the workplace may increase recognition and promote the prevention of HRI. Additional systematic characterization of occupational HRI risk factors is needed.

REFERENCES


