Occupational Heat-Related Illness Emergency Department Visits and Inpatient Hospitalizations in the Southeast Region, 2007–2011

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Background *Heat-related illness (HRI) is an occupational health risk for many outdoor, and some indoor, workers.*
Methods *Emergency department (ED) and inpatient hospitalization (IH) data for 2007–2011 from nine southeast states were analyzed to identify occupational HRI numbers and rates, demographic characteristics, and co-morbid conditions.*
Results *There were 8,315 occupational HRI ED visits (6.5/100,000 workers) and 1,051 IHs (0.61/100,000) in the southeast over the study period. Out-of-state residents comprised 8% of ED visits and 12% of IHs. Rates for both, ED visits and IHs were significantly elevated in males and blacks. Younger workers had elevated rates for ED visits, while older workers had higher IH rates.*
Conclusions *This is the first study to evaluate occupational HRI ED visits and IHs in the southeast region and indicates the need for enhanced heat-stress prevention policies in the southeast. Findings from this study can be used to direct state health department tracking and evaluation of occupational HRI. Am. J. Ind. Med.* © *2015 Wiley Periodicals, Inc.*

***KEY WORDS:* heat; occupational; southeast; hospitalization; emergency department**

INTRODUCTION

Heat stress is a recognized occupational hazard for individuals who work in an environment where their body is unable to dissipate excess internal heat resulting in heat-related illness (HRI). Workers at risk of HRI include outdoor workers, such as farmers, construction workers, postal workers, transportation, oil and gas workers, and individuals

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who work in hot environments such as firefighters and factory workers [Jay and Kenny, 2010; Hanna et al., 2011]. Also at risk are warehouse and other indoor workers who work in non-climate controlled indoor environments [Jay and Kenny, 2010; Hanna et al., 2011; Soper, 2011].

The human body typically maintains a narrow internal temperature range (37°C ± 0.5). When the internal temperature increases above this range, a series of compensatory mechanisms such as sweating and increased blood flow are induced to emit excess heat. In situations of extreme internal heat resulting from environmental and exertional factors, such as heavy physical labor, the body's coping mechanisms are compromised, resulting in a cascade of outcomes ranging from minimal adverse health effects (e.g., heat edema or heat cramps) to severe adverse effects such as heat exhaustion or heat stroke which can result in multi-organ failure and possibly death. Although HRI can occur at any temperature, individuals who work in hot and humid environments are at an increased risk because high humidity impairs the body's sweating mechanism [Vander et al., 2001].

There are many studies documenting heat-related morbidity and mortality in the general population [Basu et al., 2002; Basu, 2009; Gosling et al., 2009; Romero-Lankao et al., 2012; Ye et al., 2012], yet there is limited epidemiological data on occupational HRI within the non-military population. The limited occupational data indicate, however, that workers are at an increased risk for HRI because unlike the general population who has greater liberty to respond to environmental changes, workers' exposure and response to heat is controlled by the requirements of their jobs and employers [Roelofs et al., 2014]. Data from the Bureau of Labor Statistics (BLS) indicate that in 2013 there were 3,160 HRI cases due to exposure to environmental heat resulting in one or more days of lost work, and 34 fatalities (Bureau of Labor Statistics, 2014). These numbers are underestimated since BLS does not capture all nonfatal illnesses or deaths. Between 1992 and 2006, there were 423 occupational heat-related deaths with 24% (n = 102) occurring among workers in the agricultural, forestry, fishing, and hunting industries [CDC, 2008]. A study of workers' compensation claims in Washington State found that certain industry/occupations and sub-sectors had highest rates of HRI compared with other industry/occupations and sub-sectors: fire protection industry had a claim rate of 80.8/100,000 full-time equivalents (FTE) while roofing construction industry had a rate of 59.0/100,000 FTE [Bonauto et al., 2007]. A North Carolina study of Emergency Department (ED) visits found that work-related HRI visits were more common than non-occupational causes (i.e., exercise/recreation) in 19–45-year-olds [Rhea et al., 2012]. A 2013 study of migrant farmworkers in Georgia found that one-third had experienced three or more HRI symptoms during the preceding week and many faced barriers at work to prevent HRI, such as the unavailability of shady areas to take breaks in [Fleischer et al., 2013].

Identifying the magnitude of occupational HRI through numbers and rates is important because excessive heat exposure will likely worsen in coming years as predicted changes in weather patterns will result in longer and hotter summers [Intergovernmental Panel on Climate Change, 2014]. August 2014 was the warmest August on record for the globe since records began in 1880, beating the previous record set in 1998; and August 2014 marked the 38th consecutive August with a temperature above the 20th century average [National Oceanic and Atmospheric Administration, 2014]. Despite data documenting HRI in select working populations, there is scant data on occupational HRI among workers in the southeastern United States (US). A recent paper looking at occupational HRI mortality reported that 6 of the 10 states with the highest occupational HRI mortality for 2000–2010 were in the southeast [Gubernot et al., 2014]. Outdoor workers in the subtropical southeastern climate represent some of the most at-risk workers in the US and reliable surveillance data are needed to document the magnitude of the problem, identify high-risk workers, and inform prevention measures and policy changes. This paper provides a descriptive look at occupational HRI in the southeastern US and presents an HRI data surveillance model that can be used by other state public health officials.

MATERIALS AND METHODS

Inpatient hospitalization (IH) and emergency department (ED) data from 2007 to 2011 were obtained from nine southeastern states (Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia) with the following exceptions: Mississippi (Hospitalization and ED data 2010–2011 only), Kentucky (ED data 2008–2011 only), Louisiana (ED data 2010–2011 only), North Carolina (ED data 2008–2011 only), and Virginia (no ED data). All available primary and secondary diagnosis fields and external cause of injury (Ecode) fields were used to identify HRI (ICD-9-CM 992.0-992.9 and E900.0, E900.1, E900.9). Workers admitted to the hospital regardless of admission source (e.g., ED or physician referral) were classified as an IH. Data were restricted to individuals age 16 years and older to reflect the working population. Work-relatedness was identified through workers' compensation as the expected payer or the presence of a work-related Ecode [Alamgir et al., 2006]. The algorithm for work-related Ecodes is as follows: civilian work (E000.0), military work (E000.1), work-related transportation (E800–E807, 4th digit = 0; E830–E838, 4th digit = 2 or 6; E840–E845, 4th digit = 2 or 8; E846), or location (E849.1–E849.3). A summary of data availability for each state can be found in Table I.

The descriptive analysis was stratified by in-state residence and out-of-state residence (non-residents) status.

TABLE I. Emergency Department (ED) and Inpatient Hospitalization (IH) Data Field Availability by Southeastern State, 2007–2011

State	Number of diagnosis fields	Number of ecode fields	Number of payer fields	Data availability	Available variables
Florida	ED = 10 IH = 31	ED = 3 IH = 3	ED = 1 IH = 1	ED/IH: 2007–2011	Age Sex Race Ethnicity
Georgia[a]	ED = 10 IH = 10	ED = 0 IH = 0	ED = 3 IH = 3	ED/IH: 2007–2011	Age Sex Race Ethnicity[b]
Kentucky	ED = 25 IH = 25	ED = 3 IH = 3	ED = 3 IH = 3	ED = 2008–2011 IH = 2007–2011	Age Sex Race Ethnicity
Louisiana[a]	ED = 24 IH = 12	ED = 0 IH = 1	ED = 1 IH = 3	ED/IH: 2010–2011	Age Sex Race
North Carolina	ED = 11 IH = 9	ED = 5 IH = 1	ED = 1 IH = 2	ED = 2008–2011 IH = 2007–2011	Age Sex Race[b] Ethnicity[b]
South Carolina[a,c]	ED= 15 IH = 15	ED = 1 IH = 1	ED = 3 IH = 3	ED/IH: 2007–2011	Age Sex Race Ethnicity
Mississippi[a]	ED = 11 IH = 11	ED = 1 IH = 1	ED = 3 IH = 3	ED/IH: 2010–2011	Age Sex Race Ethnicity
Tennessee	ED = 18 IH = 18	ED = 3 IH = 3	ED = 3 IH = 3	ED/IH: 2007–2011	Age Sex Race Ethnicity
Virginia	IH = 18	IH = 3	IH = 1	ED/IH: 2007–2011	Age Sex Race Ethnicity

[a]Ecodes were found in the diagnosis fields and, if available, the Ecode fields.
[b]North Carolina: Race and ethnicity are not available in the ED data. Race and ethnicity was not uniformly reported by North Carolina hospitals across the state.
Georgia: Ethnicity was not available for the years 2007–2008.
[c]In October of 2007, South Carolina went from 10 diagnosis code fields to 15 diagnosis code fields in both ED and IH data sets.

Non-residents were included in the analysis to present a more accurate estimate of occupational HRI since workforces increasingly include workers from other states and countries. Occupational HRI rates were calculated for state residents only. The denominator for rate calculations was the employed population for each state for the corresponding years obtained from the Current Population Survey (CPS) for those *employed at work* or *employed absent*. The CPS is a monthly household survey administered by the US Bureau of Labor and US Census Bureau. Data (numerator and denominator) were categorized by sex, race (white, black, other), ethnicity (Hispanic/non-Hispanic), and 5-year age groups (16–19, 20–24, 30–34. . .60–64 and 65 years and older). Supplemental Table SI provides information on how each data source originally categorized race and ethnicity. Where appropriate, aggregated rate ratios and their corresponding 95% confidence intervals were calculated. State-specific and total southeast rates were age-adjusted using direct standardization. The population weights obtained from the CPS were the 2007–2011 total employed population for the US.

Population data for non-residents were not available; instead, the proportion of non-residents by all HRI ED visits and IHs was reported. The following comorbid conditions co-diagnosed with occupational HRI ED visits and IHs were examined: cardiovascular disease (ICD-9-CM codes 390–398, 404–429, 440–448, and 402), cerebrovascular disease (ICD-9-CM codes 430–438), respiratory disease (ICD-9-CM codes 460–519), renal disease (ICD-9-CM codes 580–589), diabetes (ICD-9-CM code 250), and all injuries (ICD-9-CM codes 800–904). Note that for each of these diseases (except injury), the diagnosis codes include complications of a current event or complications resulting from a past event (e.g., ICD-9-CM 412: old myocardial infarction). Each state provided summary statistics for length of hospital stay.

RESULTS

Work-Related HRI Visit Identification

For the 5-year study period (2007–2011), there were a total of 8,315 ED visits (7,664 residents and 651 non-residents) and 1,051 IHs (930 residents and 121 non-residents) for occupational HRI in the southeast region (Table II). ICD-9-CM diagnosis codes for HRI (992.0–992.9) identified almost all of the occupational HRI ED visits; only 3.1% of ED visits for residents and 3.8% of ED visits for non-residents were identified solely by Ecodes for accidents caused by excessive heat (E900.0, E900.1, E900.9). The majority of ED visits with ICD-9-CM HRI codes also had Ecodes for accidents caused by excessive heat (residents: n = 6,519 [85.1%], non-residents: n = 532 [81.7%]). For IHs, a small percentage of occupational HRI hospitalizations were identified through Ecodes (E900.0, E900.1, E900.9) with no supporting diagnostic codes (residents: n = 19 [2.0%]; non-residents: n = 1 [0.8%]). Similar to ED visits, the majority of occupational HRI IHs identified by a HRI diagnosis code also had at least one Ecode for an accident caused by excessive heat (residents: n = 701 [76.9%]; non-residents = 92 [76.7%]).

Occupational status was determined by expected payer or through the work-related Ecode algorithm. The expected primary payer of workers' compensation code alone identified 60% of all occupational HRI ED visits and IHs and the use of the work-related algorithm alone identified an additional 32% of all occupational HRI visits (Table II). The combination of both requiring the expected primary payer of workers' compensation and the work-related Ecode algorithm identified only 8% of the total visits; therefore, mutually exclusive analysis of both the expected payer of workers' compensation and the work-related algorithm are necessary to identify occupational HRI. The proportion of ED visits identified by workers' compensation payment alone varied from 80.4% in Kentucky to 50.2% in South Carolina. South Carolina had the lowest proportion of occupational HRI hospitalizations identified solely by workers' compensation (38.3%); North Carolina had the highest proportion (83.7%) followed by Kentucky (80.4%).

Emergency Department Visits

Eight southeastern states provided ED data on occupational HRI. The overall age-adjusted rate of occupational HRI ED visits among residents in the southeastern US was 6.5 ED visits per 100,000 workers (95%CI = 6.4, 6.7) (Fig. 1). State specific age-adjusted rates ranged from 4.8/100,000 workers in Florida to 17.3/100,000 workers in Louisiana. The percentages of out-of-state resident occupational ED visits ranged from 3.9% in Florida to 15.1% in Louisiana. State specific rates and percentages may not be directly comparable because the ED and IH data collection process, identification, and use of work-relatedness (expected payer field and Ecode fields) can vary by state (Tables I and II).

Occupational HRI ED visit rates were highest for males (Relative Risk [RR] = 5.7, 95%CI = 5.3, 6.1) and minority workers (i.e., black and other race) (RR = 1.4, 95%CI = 1.3, 1.5) (Table III). Hispanics had a lower rate of occupational HRI ED visits than non-Hispanics (RR = 0.54, 95%CI = 0.5, 0.6). Workers ages 16–34 years had the highest rates of occupational HRI ED visits (Fig. 2). After the age of 35 years, occupational HRI ED visit rates decreased with age. The distribution of sex, race, and ethnicity were similar for residents and non-residents (data not shown). For age, the distribution was similar except among the following groups: a larger proportion of non-residents were ages 20–24 years (residents = 12.8%, non-residents = 17.1%) while a larger proportion of residents were ages 30–34 years (residents = 14.2%, non-residents = 11.7%).

TABLE II. Work-Related Selection Criteria for Occupational Heat-Related Illness in Southeast Region, 2007–2011

	Emergency department (ED) visits (%)		Inpatient hospitalizations (IH) (%)		
Work-related slection criteria	Residents	Non-residents	Residents	Non-residents	Total
Expected primary payer of workers' compensation	4,575 (60)	410 (63)	577 (62)	82 (68)	5,644 (60)
Ecode algorithm	2,455 (32)	189 (29)	300 (32)	32 (26)	2,976 (32)
Ecode algorithm + Expected primary payer of workers' compensation	634 (8)	52 (8)	53 (6)	7 (6)	746 (8)
Total	7,664	651	930	121	9,366

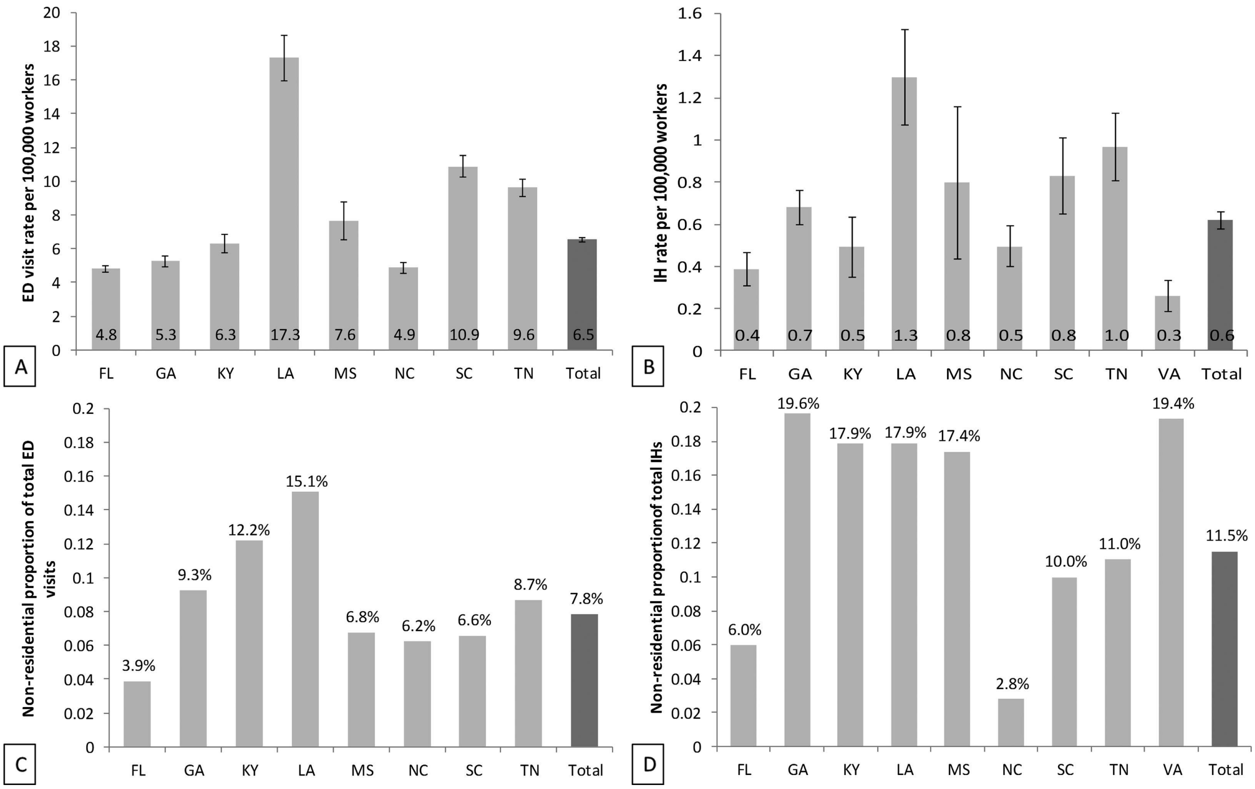


FIGURE 1. Rates of Southeast Region Resident Occupational Heat-related Illness Emergency Department Visits (**A**) and Inpatient Hospitalizations (**B**), and Proportion of Non-Resident Occupational Heat-related Illness Emergency Department Visits (**C**) and Non-Resident Inpatient Hospitalizations (**D**), 2007–2011. Total overall southeastern state rates and proportions are presented in dark gray. Note the rates for Emergency Department Visits are an order of magnitude higher than the rates of Inpatient Hospitalizations.

As expected, the majority of occupational HRI ED visits for both residents and non-residents occurred during the hottest months (June–August) (Fig. 3). However, over 10% of all visits occurred in May and September, and ED visits occurred throughout the entire year. The majority of ED visits occurred on Wednesday and Thursday for residents (20.5% and 19.3%, respectively) and on Tuesday for non-residents (19.2%). Approximately 17.1% (n = 1303) of all occupational HRI ED visits among residents had a diagnosis code for at least one comorbid condition. Of the 1,303 visits with a comorbid condition, the most frequent comorbidities were: cardiovascular outcome/history (n = 316; 24.3%), diabetes (n = 332; 24.7%), and an injury diagnosis (n = 249; 19.1%) (Fig. 4).

Inpatient Hospitalizations

Nine southeastern states provided IH data on occupational HRI. The overall age-adjusted rate of occupational HRI IHs among residents was 0.61/100,000 workers (95%CI = 0.58, 0.66) (Fig. 1). The average length of stay was 2.7 days for residents (SD = 3.9) and 2.4 days for non-residents (SD = 2.1).

The rate of occupational HRI IHs among residents was significantly higher for males compared to females (RR = 20.7; 95%CI = 15.0, 28.5). Compared with whites, the HRI hospitalization rate was 1.5 times higher for blacks (95% CI = 1.3, 1.8) and 3.4 times higher for other minorities (95% CI = 2.8, 4.2). The HRI IH rate was also higher for Hispanics compared with non-Hispanics (RR = 1.5, 95%CI = 1.2, 1.8). The proportion of occupational HRI IHs by sex was similar for residents and non-residents (data not shown). However, among the nine southeastern states that collected the information, a greater proportion of non-residents than residents were missing information on race (residents = 6.1%; non-residents = 9.1%) and ethnicity (residents = 15.3%; non-residents = 17.0%). Additionally, a larger proportion of non-residents who were hospitalized were Hispanic (residents = 12.2%; non-residents = 17.0%).

The rate of occupational HRI IHs among residents peaked at ages 35–39 years (rate = 0.9/100,000 workers) with similar rates among those age 40 years and older (Fig. 2). Among non-residents, the proportion of

TABLE III. Southeast Region Occupational Heat-Related Illness (HRI) Emergency Department (ED) Visits and Inpatient Hospitalizations (IH) by Demographic Characteristics, 2007–2011[a]

	Occupational HRI ED visits				Occupational HRI IH			
Characteristic	**N**	**(%)**	**Rate[b]**	**RR (95%CI)[c]**	**N**	**(%)**	**Rate[b]**	**RR (95%CI)[c]**
Sex								
Male	6615	86.3	10.7	5.7 (5.3, 6.1)	891	95.8	1.14	20.7 (15.0, 28.5)
Female	1048	13.7	1.9	1.0	39	4.2	0.055	1.0
Missing	1	0.0			0			
Race								
White	4878	71.0	6.2	1.0	561	60.3	0.5	1.0
Black	1547	22.5	8.2	1.3 (1.3, 1.4)	210	22.6	0.8	1.5 (1.3, 1.8)
Other	350	5.1	9.9	1.6 (1.5, 1.8)	102	11.0	1.7	3.4 (2.8, 4.2)
Missing	94	1.4			57	6.1		
Ethnicity								
Non-Hispanic	5161	83.1	6.4	1.0	584	72.5	0.5	1.0
Hispanic	387	6.2	3.4	0.5 (0.5, 0.6)	98	12.2	0.7	1.4 (1.2, 1.8)
Missing	665	10.7			124	15.4		

[a]Total case numbers differ for each category since Louisiana (ED/IH) and North Carolina (ED) do not collect Ethnicity data, North Carolina (ED) does not collect race data, and Georgia (ED/IH) did not collect race and ethnicity data for 2007–2008. The denominator data for the HRI rates by race and ethnicity reflects the person-time associated with available case numbers (i.e., numerator data).
[b]All rates are per 100,000 workers.
[c]All rate ratios (RR) have a P-value <0.001.

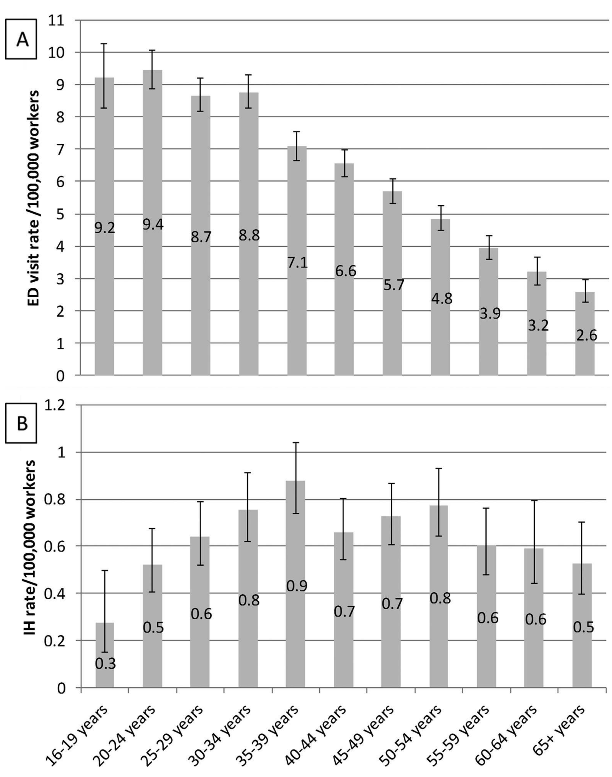


FIGURE 2. Rates of Southeastern Region Resident Occupational Heat-Related Illness Emergency Department (ED) Visits (**A**) and Inpatient Hospitalizations (IH) (**B**) by Age Category, 2007–2011.

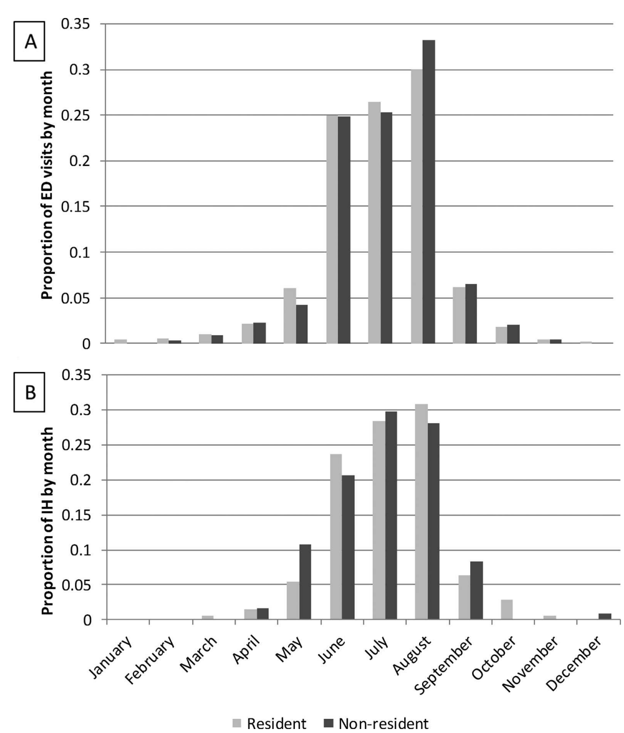
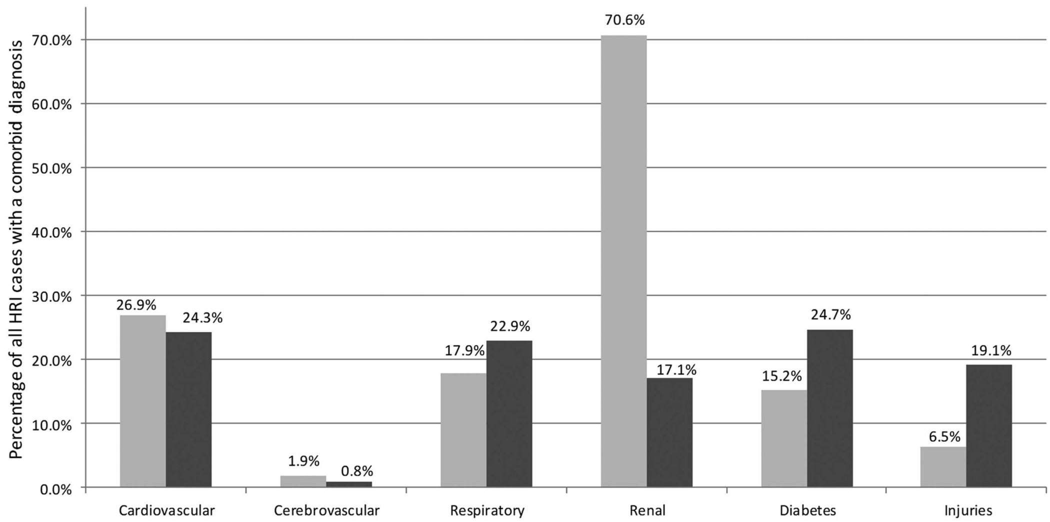


FIGURE 3. Proportions of Southeastern Region Occupational Heat-Related Illness Emergency Department (ED) Visits (**A**) and Inpatient Hospitalizations (IH) (**B**) by Residency Status and Month of Occurrence, 2007–2011.



	Cardiovascular	Cerebrovascular	Respiratory	Renal	Diabetes	Injuries
IH (N = 620)	167	12	111	438	94	40
ED visits (N = 1303)	316	11	299	223	332	249

FIGURE 4. Southeastern Region Occupational Heat-Related Illness (HRI) Emergency Department (ED) Visits and Inpatient Hospitalizations (IH) with Comorbid Condition Diagnoses, 2007–2011. Comorbid conditions are not mutually exclusive.

occupational HRI hospitalizations varied by age group. A larger proportion of non-residents younger than 25 years of age were hospitalized compared to residents (residents = 8.7%; non-residents = 17.4%) and in turn, a smaller proportion of older (≥60 years) non-residents were hospitalized than older residents (residents = 8.7%; non-residents = 5.0%).

Occupational HRI IHs occurred throughout the year with the majority occurring in June, July, and August (resident = 82.8%; non-residents = 78.5%), the hottest summer months (Fig. 3). Unlike the occupational HRI ED visits, the proportion of occupational HRI IHs in May was higher among non-residents (10.7%) than among residents (5.5%). The majority of IHs occurred on Wednesday and Thursday for residents (23.7% and 21.5%, respectively) and on Tuesday and Wednesday for non-residents (22.3% for both days). Among residents, 67% (n = 620) of all occupational HRI IHs had one or more comorbid conditions. Renal conditions were more pronounced among IHs than ED visits (70.6% [n=438] vs. 17.1%, respectively). Additionally, 26.9% (n=167) of the 620 comorbid IHs were for a cardiovascular outcome/history and 17.9% (n=111) were for a respiratory outcome/history (Fig. 4).

Fatalities

This review identified eight workers who died from HRI. This number reflects only those occupational HRI cases who were treated in the ED or hospitalized and may not include all occupational heat-related fatalities during this time period for the southeast region. For instance, the BLS reported 36 deaths due to environmental heat for 2007–2011 for the nine states included in this study (Bureau of Labor Statistics, 2015).

DISCUSSION

This paper provides critical information about the impact of excessive heat on workers and is the first study, to our knowledge, that provides ED and IH rates for occupational HRI in the US and particularly, in the subtropical southeast region. Coordinated through a regional occupational health network of 12 southeastern state health departments or bonafide agents (Southeastern States Occupational Network [South ON]), we were able to access and analyze ED and IH data collected from nine state health departments. This coordinated effort resulted in both a comprehensive assessment of occupational HRI in the southeast, and provides a surveillance framework for tracking and assessment of occupational HRI.

The occupational HRI rates observed in the southeast region of the US in this study are higher than those observed in other North American occupational HRI studies, and may potentially indicate hazardous climatic exposures (i.e., hot and humid) in the southeast region of the U.S [Bonauto et al., 2007; Fortune et al., 2013; Adam-Poupart et al., 2014]. Although the aforementioned studies are not directly comparable and other factors may explain differences in rates (e.g., data source, HRI prevention efforts, employment patterns, etc.), they do provide a general comparison and support the importance of focusing on the southeast for prevention of occupational HRI. A recent analysis of heat-related hospitalizations in 20 states by CDC's Environmental Public Health Tracking Program found that three southeastern states were among the five states with the highest HRI hospitalization rates. Although the study included occupational and non-occupational cases as well as a limited number of states, the findings highlight the regional variation in HRI [Choudhary, 2014].

Out-of-state residents are typically excluded from analysis of state-level datasets because of denominator issues. While their omission may have limited impact on evaluation of chronic conditions, their inclusion for acute conditions like HRI provides a more accurate assessment of heat stress among a state's working population. In addition, out-of-state workers may be at higher risk than residents due to job type, immigration status, or acclimatization. During the study period, out-of-state residents accounted for 7.8% and 11.5% of occupational ED visits and IHs, respectively. Louisiana, Kentucky, and Georgia had the highest percentages (>9%) of out-of-state resident occupational ED visits. For comparative purposes, 8.5% of all occupational ED visits (including HRI) in Kentucky were among out-of-state residents, approximately 4% lower than for Kentucky occupational HRI ED visits (Kentucky Injury Prevention and Research Center [KIPRC], personal communication). Out-of-state resident percentages were above 15% for five of the nine southeastern states for occupational HRI IHs, with the highest percentages observed in Georgia, Virginia, Kentucky, and Louisiana. In comparison, out-of state residents accounted for 15% of all occupational IHs (including HRI) in Kentucky over the same study period, 3% lower than for occupational HRI IHs (KIPRC, personal communication). Out-of-state workers include a variety of employment arrangements such as workers commuting in from neighboring states, migrant workers on a temporary work visa, or workers temporarily living and working in a different state. Out-of-state commuting data indicate that approximately 4% of workers in the southeast work in a state other than where they live. State-specific numbers range from 7.8% in Kentucky to a 0.7% in Florida (US Census Bureau, 2011).

The large number of out-of-state residents with occupational HRI may indicate that out-of-state workers were not well acclimated to the heat and humidity in the southeast region. Insufficient acclimatization has been shown to be a major risk factor for HRI. In a review of 13 cases of occupational heat-related deaths investigated by the Occupational Safety and Health Administration (OSHA), most of the deaths occurred in the first 3 days of working, and four occurred on the workers' first day [Arbury et al., 2014]. Similar findings were recorded in 25 heat-related enforcement investigations conducted by the California Division of Occupational Safety and Health (Cal/OSHA) during May through November 2005. It was the first day on the job for 46% of the workers, and 80% had been on the job for four or fewer days [Prudhomme, 2006]. Research has shown that repeated exposure to hot environments over a 10–14 day period results in physiologic adaptive benefits including increased sweating efficiency and stabilization of circulation [CDC, 1986]. OSHA suggests gradual acclimatization: 20% of usual work duration in heat the first day, increasing 20% each subsequent day.

Most of the occupational HRI cases observed in this study were men (86% of ED visits and 96% of IHs). This finding reflects the male-dominated occupations at highest risk for heat exposure: agriculture, forestry and fishing, construction, extraction (particularly oil and gas activities), and transportation and warehousing. The elevated percent of male cases among HRI has been documented by other researchers: 87% [Florida Department of Health, 2012]; 80% [Bonauto et al., 2007]; 100% [Prudhomme, 2006]; and nearly 100% [CDC, 2008]. The state-specific industry composition may also contribute to the difference in rates. Louisiana has a higher percentage of workers employed in mining (including oil/gas extraction) and construction than the other southeastern states. Both of these industries have high physical labor demands and regular outdoor exposure.

Our results indicate that minority workers have higher rates of HRI than white workers. Approximately one-quarter of the cases were black which reflects the overall racial workforce composition of the nine southeastern states that contributed data (mean = 20.3%; range = 6–32%) [SouthON, 2012]; however, the racial distribution of occupations at high-risk for HRI will have an impact on the observed minority HRI rates. The racial category "other" also had a significantly elevated rate compared with whites. The composition of the "other" category varies by state demographics but includes Asian, Pacific Islander, and Native American. Hispanics had lower ED visit rates and higher IH rates compared with non-Hispanics. The large number of missing data points on Hispanic ethnicity potentially limits the validity of this measure. However, a simple sensitivity analysis indicates that if all the missing data points were correctly classified the observed differences would not change (Supplemental Information). Overall, the percentage of the Hispanic population in the nine southeastern states is 8%, ranging from 3% percent in Mississippi to 24% in Florida [US Census, 2013]. While the Hispanic population is relatively small in some Southeastern states, count, census data indicate that the southeast region experienced the largest percentage increase in Hispanic population from 2000 to 2010 [Pew Research Center, 2011]. Hispanics, especially recent immigrants, are heavily employed in industries at high-risk for HRI such as agriculture and construction. Language difficulties and workplace discrimination, especially among undocumented workers, may result in lax safety training and increased exposure to hazardous conditions. Several studies have documented the high rate of HRI among Hispanic agricultural workers [Prudhomme, 2006; MMWR, 2008; Stoecklin-Marois et al., 2013). Researchers have also documented the current influx of Hispanic workers in construction in the southeast region [Rabito, 2011]. Finally, given the observed results of this study, Hispanics workers may be waiting to seek care due to other factors such as language barriers, workplace discrimination, and lack of health insurance, resulting in more severe HRI outcomes (e.g., IHs).

Occupational HRI ED visit rates decreased proportionately with age in this study, whereas occupational HRI IH rates increased to age 35–39 years then plateaued. Overall, these data suggest that HRI more commonly impacts younger workers, yet older workers were more likely to experience severe health effects resulting in IHs. Increasing age is a known risk factor for HRI and may be related to multiple factors: decreases in sweating and blood flow, changes in cardiovascular function, and decreases in overall fitness [CDC, 1986]. A study of South African gold miners found the incidence rate for men over 40 years of age was ten times greater than for men under 25 years of age [Strydom, 1971]. The elevated rate among younger workers likely reflects the employment demographics of industries most at risk for occupational HRI.

In addition to age, other pre-existing conditions such as cardiovascular/respiratory conditions or diabetes put individuals at higher risk of HRI [Basu et al., 2002; Hajat et al., 2010; CDC, 2013]. In our study, 67% of occupational HRI IHs among residents had at least one co-diagnosed medical condition that has been shown to be associated with HRI compared with 17% of co-diagnosed conditions observed among HRI ED visits. This suggests that cases with co-morbid conditions have more severe outcomes than those without co-morbid conditions. Studies have indicated that heat exposure is associated with increased risk of injuries among workers as it may result in sweaty palms, fogged-up safety glasses, and dizziness [Fogleman et al., 2005; Morabito et al., 2006; CDC, 2013; Tawatsupa et al., 2013]. This association was also observed in our study: of the ED visits with a co-morbid diagnosis, 19% had an injury diagnosis suggesting that heat stress may increase the injury rate among workers. Additionally, a common complication of exertional heat stroke is acute renal failure [Bouchama et al., 2002; Lugo-Amador et al., 2004]. Within our data, the observed high proportion of renal diagnoses among those with co-morbid conditions, especially in the IHs (IHs = 70%; ED = 17%), indicates the severity of occupational HRI.

Approximately 90% of all occupational HRI occurred during the months of May through September, summer and shoulder months that are associated with high ambient temperatures. These results are similar to a number of other HRI studies [Bonauto et al., 2007; Basu et al., 2012; Fortune et al., 2013; Arbury et al., 2014; Pillai et al., 2014]. However, our results indicate that the at-risk period may be longer in the southeast region than in the northern region. Several studies have shown an increased rate of HRI with increasing temperatures [Gosling et al., 2009; Green et al., 2010; Hanna et al., 2011; Basu et al., 2012; Williams et al., 2012]. In Quebec, Canada, between 1998 and 2010, a 42% increase in the rate of HRI workers' compensation claims was observed for every 1°C increase in temperature [Adam-Poupart, 2014]. A North Carolina study of death certificates found a 37% increase in occupational HRI deaths for every 1°F increase in temperature [Mirabelli and Richardson, 2005]. The Florida Department of Health [2012] also reported a relationship between HRI and maximum temperature and heat index. These studies suggest that as temperatures rise due to climate change there may be a considerable impact on HRI. Furthermore, with projected temperature increases from 1°C to 6°C, the high heat and humidity in the southeast may curtail working outdoors in some areas during certain months of the year [Intergovernmental Panel on Climate Change, 2014].

Currently, there are no federal regulations to protect workers from excessive heat exposure. Instead of a heat standard, OSHA is promoting a nationwide education and outreach campaign alerting employers and employees about the dangers of working in heat, and guidance on preventive measures and the establishment of worksite heat illness prevention programs. Whether this campaign is protective enough, however, is uncertain. A recent review of 2012–2013 OSHA enforcement cases indicate that many of the investigated employers had no heat illness prevention program, and those with programs lacked basic elements such as water management, shaded rest areas, work-rest cycles, and acclimatization protocols [MMWR, 2014]. The OSHA report underscores the importance of accurate and timely surveillance data on occupational HRI to determine the magnitude of the problem, identify at-risk populations, and develop prevention priorities.

Limitations

There are a number of limitations to the current study. First, occupational HRI ED visit and IH data were not available for all 12 southeastern states for all years of the study period. Second, southeastern state ED visit and IH data differ in the method of data collection and the number of data collection fields for diagnosis, Ecodes, and payer. Further, for race and ethnicity, the method of data collection (i.e., one or two variables) and categorizations (e.g., white, black, American Indian, Asian, Pacific Islander) varied by state (Table S1). Race and ethnicity data were also limited due to under-reporting. While missing data and different coding systems may affect the overall derived occupational HRI rates, the reported estimates represent the most accurate assessment to date for the southeast region. Third, not all occupational HRI may have been identified. HRI is generally under-diagnosed with some HRI cases coded as the presenting symptom (e.g., cardiovascular outcome) [Ye et al., 2012]. Further, workers' compensation is underutilized and may miss between 33–47% of work-related injuries and illnesses [CDC, 2007; Davis et al., 2012; Groenewold et al., 2013]. The addition of Ecodes for identification of work-relatedness captures many missing cases [Alamgir et al., 2006]. As this review focused only on heat-related morbidity, fatalities reported in this study were derived from ED and IH records, not from death certificates. This may result in an undercounting of total occupational heat-related fatalities. Data sources utilized for this study (ED and IH records) preclude assessment of industry or occupation. Last, HRI rates are underestimated due to inclusion of non-exposed workers in the denominator (e.g., office workers).

CONCLUSIONS

This is the first study to determine occupational HRI ED visit and IH rates in the southeast region of the US, and provides an important contribution to the current assessment and ongoing evaluation of occupational HRI. This regional collaborative study represents an occupational health surveillance framework for state health departments and occupational health partners in other regions. Elevated ED visit and IH rates were observed along with elevated out-of-state occupational HRI percentages. The large number of out-of-state HRI cases highlights the importance of including all workers regardless of residency status when evaluating occupational health conditions. It also points to the value of a regional approach for occupational health surveillance because high-risk occupational health conditions can be better identified.

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ETHICS REVIEW AND APPROVAL

Institutional Review Board (IRB) approval was obtained from the University of North Carolina. A waiver of informed consent was given as this was a retrospective study using secondary data and data are only displayed as summary statistics. IRB approval was obtained from the University of Kentucky to conduct an occupational safety and health surveillance program, for which this project falls under that IRB. Data sharing agreements were signed between each state health department and their respective data custodian.

DISCLAIMERS

The contents of this paper are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH or any the contributing State Health Departments. NC DETECT is a statewide public health syndromic surveillance system, funded by the NC Division of Public Health (NC DPH) Federal Public Health Emergency Preparedness Grant and managed through collaboration between NC DPH and UNC-CH Department of Emergency Medicine's Carolina Center for Health Informatics. The NC DETECT Data Oversight Committee does not take responsibility for the scientific validity or accuracy of methodology, results, statistical analyses, or conclusions presented.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

Work was performed at each individual state health department, the University of Kentucky, and the University of North Carolina. Individual state results were compiled at the University of North Carolina.

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