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Characterizing Occupational Heat-Related Mortality in the United States, 2000–2010: An Analysis Using the Census of Fatal Occupational Injuries Database

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Abstract

Background—Occupational heat-related mortality is not well studied and risk factors remain largely unknown. This paper describes the epidemiological characteristics of heat-related deaths among workers in the US 2000–2010.

Methods—Fatality data were obtained at the Bureau of Labor Statistics from the confidential on-site Census of Fatal Occupational Injuries database. Fatality rates and risk ratios with 95% confidence intervals were calculated by year, sex, age group, ethnicity, race, state, and industry.

Results—Between 2000 and 2010, 359 occupational heat-related deaths were identified in the U.S., for a yearly average fatality rate of 0.22 per 1 million workers. Highest rates were found among Hispanics, men, the agriculture and construction industries, the state of Mississippi, and very small establishments.

Conclusions—This study provides the first comprehensive national profile of heat-related deaths in the U.S. workplace. Prevention efforts should be directed at small businesses and at industries and individuals with the highest risk.

Introduction

As climate change effects gradually progress, the importance of understanding and preventing heat stress in the population becomes increasingly imperative. Within the last decade, numerous studies have associated extreme heat with mortality [Basu and Samet, 2002; Curriero et al., 2002; Hajat et al., 2006; Anderson and Bell, 2011] and identified sub-populations particularly vulnerable to heat [Semenza et al., 1996; Wainwright et al., 1999; Stafoggia et al., 2006; Rey et al., 2007; Gabriel and Endlicher, 2011]. Environmental heat exposure is directly associated with an average of 618 fatalities/year in the U.S. [CDC, 2012], making heat the leading cause of weather-related deaths, above lightening, tornadoes, hurricanes, and floods combined [NOAA, 2011]. Further, these heat-fatality estimates likely exclude deaths for which heat was a discreet contributory cause (e.g., myocardial infarctions). High temperatures are also strongly associated with population-level increases in hospitalizations for cardiovascular, respiratory, and other illnesses, as well as excess emergency department visits [Semenza et al., 1999; Wainwright et al., 1999; Braga et al., 2002; Schwartz et al., 2004; Dolney and Sheridan, 2006; Knowlton et al., 2009].

Less is known about occupational heat-related morbidity and mortality, since most previous studies have focused on population-level heat effects, despite added occupational factors that may translate into greater overall heat-related health risks in the workplace. Workers are sometimes required to perform exertional work tasks while exposed to high ambient temperatures, increasing vulnerability to heat-related health effects. Physical strain and increased metabolic heat load can trigger accidents through physical fatigue, impaired mental capacity, and misuse of personal protective equipment (PPE) [Ramsey, 1995; Park et al., 2009; Rowlinson et al., 2013]; PPE restricts heat loss from the body and becomes problematic to employees working in the heat [Crockford, 1999].

Despite the potential of heat stress as an occupational hazard, there are no federal government standards to protect workers. The extent of heat-related injuries and illnesses (HRI) in U.S. workers is not known, although in 1986, the National Institute for Occupational Safety and Health (NIOSH) estimated 5 to 10 million employees are exposed yearly [NIOSH, 1986]. The published works on occupational HRI are limited and generally focus on particular events, outcomes, states, or industries [Gubernot et al., 2013]. For example, previous studies have investigated heat-related fatalities specifically in agricultural workers [Luginbuhl et al., 2008] and in the state of North Carolina [Mirabelli and Richardson, 2005], and heat-related morbidity in miners [Donoghue, 2004], responders to the Deep Water Horizon Gulf Oil Spill of April 2010 [King and Gibbons, 2011], the military [Gardener et al., 1996; Epstein et al., 1999; Carter et al., 2005], and workers in the states of Washington [Bonauto et al., 2007; Bonauto et al., 2010] and Florida [Florida DOH, 2011].

To our knowledge, no prior study has described the epidemiology of U.S. occupational heat-related fatalities over multiple years, including all industries and states. The study aims are 1) to describe overall rates by year, industry, and state; 2) to describe the demographic characteristics of the cases; and 3) to use these data to determine groups at highest risk for targeted prevention efforts. Although this article specifically focuses on fatal HRI occupational events, insights from these findings could be applied to broader heat illness prevention efforts.

Material and Methods

Data Sources

Fatality data were obtained at the Bureau of Labor Statistics (BLS) from the confidential on-site Census of Fatal Occupational Injuries (CFOI) database. The database represents all identified worker fatalities including those outside the scope of the Occupational Safety and Health Administration’s (OSHA) coverage, such as volunteers [BLS, 2002]. Undocumented workers are included in CFOI as are military personnel stationed in the U.S. A heat-related death is identified in CFOI as an exposure to environmental heat with the BLS Occupational Injury and Illness Classification System event/exposure code 321 and the nature code of 072. Event and nature codes for environmental heat deaths reported 2000 through 2010 were queried and confirmed as related to environmental heat by reviewing the case narratives. The data reported in this paper are presented per BLS guidelines for confidentiality; however, all data are included in our analyses.

The Current Population Survey (CPS) provides denominator data for employed individuals and includes all employed civilian non-institutionalized workers ≥ 16 years of age. These CPS data are available on the BLS website for rate determination.

Institutional Review Board approval was not required for this research as the records are of deceased persons and there are no linkages to identifying information; data are displayed as summary statistics only. For the same reasons, informed consent was not required. A data confidentiality agreement was signed by the Bureau of Labor Statistics and the George Washington University.

Variable Definitions and Codes

The following CFOI variables were included in the analyses: sex; age; age group; race; ethnicity; month; time of day; day of week; county; state; establishment size; ownership type; employee status; industry; date of incident; and date of death.

Demographic Variables—Age was utilized as a continuous variable and also categorically as classified by BLS. We also dichotomized the age variable as younger (<55 years old) and older (≥ 55 years old). The age of death was used in the calculations; in nearly every case, age of death and age of incident (exposure) were the same. The BLS classification for sex, race, and Hispanic origin were also used.

Temporal and Geographical Variables—CFOI includes workers in all 50 states and the District of Columbia. The BLS classification for month, time of day, day of week, and state were used. The state variable refers to the state of exposure. We calculated the “time survived” variable which was dichotomized into “death on day of exposure” and “death after day of exposure”.

Establishment and Industry Variables—We utilized the BLS industry sector codes, establishment size, and ownership type classifications. The BLS utilizes the North American Industry Classification System (NAICS) to assign industry codes. Prior to 2003, the BLS applied the Standard Industrial Classification Industry Group codes. The agency implemented changes in industrial classification to better measure economic activities and to include newer industries and sub-sectors [BLS, 2013]. We accounted for and addressed the differences in these systems for appropriate industry classification in these analyses. We determined heat-related fatality rates for the BLS NAICS-aggregated industry sectors. Based on these preliminary data, we categorized industries by the three sectors with the highest rates: 1) Agriculture, Forestry, Fishing and Hunting - NAICS code 11; 2) Construction - NAICS code 23; 3) and Administrative and Support and Waste Management and Remediation Services - NAICS code 56, which we refer to as Support, Waste and Remediation Services. All other industries served as the referent group.

Statistical Analysis

Data were extracted, managed and analyzed using Microsoft Excel (Microsoft, Redmond, WA). Injury rates were calculated as number of deaths per 1,000,000 workers. The numerators indicate the number of deaths and denominator data are estimates from the CPS. Average annual incidence rates were calculated for each group. Risks were calculated using rate ratios with 95% confidence intervals (CI) as described by Rothman [Rothman and Greenland, 2008].

Deaths of volunteers, individuals < 16 years of age, and military personnel were included in the counts but removed from the rate analyses as they are not represented in the CPS denominator data.

Results

Yearly Occupational Heat-Related Mortality Rates

Our analysis of CFOI record data from 2000 to 2010, identified 359 worker deaths reported due to exposure to environmental heat in the U.S. There were five volunteers and 15 military personnel included in this total; no workers < 16 years old were identified.

The average annual heat-related fatality rate was 0.22 deaths per 1 million workers. For the study time period of 2000–2010, the highest rates were in 2005 (0.32) and 2006 (0.30), followed by 2002 and 2010 with rates of 0.29; the lowest rate was in 2004 (0.11). We dichotomized the study period into “earlier” (2000–2004) and “later” (2005–2010) and found a higher rate for the latter years (0.25 vs. 0.18) with a rate ratio (RR) of 1.4 (95% CI: 1.1, 1.7).

Demographic Characteristics

The distribution of demographic characteristics for the 359 fatalities is summarized in Table I. Only 10 cases were female. Males had a significantly higher rate compared to females, with an RR of 32.0 (95% CI: 17.0, 60.0). When rates in the agriculture and construction industries were stratified by sex, males continued to have higher rates. However, in accordance with BLS publishing criteria, these data are not reported here.

The median age of deceased workers was 41 years old. There was no significant difference in HRI fatality rates among age groups with the exception of the ≥ 65-year stratum. This group had a slightly significant increased rate of 0.34 with an RR of 2.2 (95% CI: 1.1, 4.4). Age groups dichotomized as < 55 years and ≥ 55 years had nearly identical rates (Table I).

Higher rates were associated with ethnicity and race. Blacks had an RR of 1.5 (95% CI: 1.1, 2.0) compared to whites. Notably, Hispanics compared to non-Hispanics had an RR of 3.2 (95% CI: 2.5, 4.0) and an average yearly fatality rate of 0.54 per 1 million workers (Table 3-1). When rates were stratified by ethnicity in the agriculture and construction industries, the same pattern was observed. Hispanics had an RR of 3.4 (95% CI: 2.0, 5.8) when compared to non-Hispanics in agriculture and an RR of 1.7 (95% CI: 1.1, 2.6) in construction (data not shown).

Mortality Rates by Industry and State

Table II displays the industries with the highest average annual rates of heat-related mortality: Agriculture (3.06 per 1 million workers), Construction (1.13), and Support, Waste and Remediation Services (0.56). All other industry sectors served as the referent group. In comparison to the referent group, agriculture had more than 35 times the risk of heat-related death and construction had 13 times the risk; these two industries accounted for 207 (58%) of the cases. Support, Waste and Remediation Services had an RR of 6.4 (95% CI: 4.4, 9.4).

Similarly, Table III shows average annual HRI fatality rate and risk ratios among the ten states with the highest rates. Mississippi had the highest rate of 1.05 per 1 million workers, followed by Arkansas (0.66), Nevada (0.63), West Virginia (0.60), and South Carolina (0.52). The risk in Mississippi was more than 6 times that of the 40-state reference group. Texas, which accounted for 43 deaths, had a rate of 0.33 (data not shown). California, with 45 deaths, had a rate of 0.24 which was only slightly higher than the U.S average death rate of 0.22 (data not shown). These two states account for almost 25% of the deaths from 2000–2010 while 40% of deaths were attributed to the ten high-risk states listed in Table III.

Temporal and Establishment Characteristics

The largest number of deaths occurred during July (34%) with the vast majority of the cases occurring in the summer months of June–August (86%). The majority of the workers (65%) fell ill in the afternoon hours between 12 noon and 6:00 pm. Approximately 90% of the cases occurred during the normal work week of Monday–Friday. Most workers died on the day of exposure (71%).

Private industry accounted for 321 deaths (89%) and 21 deaths occurred in the federal government, primarily U.S.-based military personnel. Of the 244 cases that reported establishment size, the largest proportions of cases were in very small establishments of less than 10 employees (43%) and very large establishments of greater than 100 employees (27.5%). We cannot determine the risk of small establishments as BLS denominator data for establishment sizes differ from CFOI size categories.

Discussion

Our study, the largest nationally representative epidemiological study on occupational HRI fatalities, demonstrates the importance of these preventable deaths. There is clearly a need to develop more effective HRI prevention programs to reduce worker heat-related morbidity and mortality. The findings identified the contribution of various factors to occupational HRI fatalities which include sex, race, ethnicity, industry sector, and state.

There was no distinguishable year-to-year trend in fatalities from 2000 to 2010. However, dichotomizing the study time resulted in a slightly, but statistically significant, higher rate in the latter half of the decade. This suggests that the yearly rates reflected fluctuating weather patterns.

Working men die of heat-related illness far more than women. Compared to females, men had 32 times the risk of a work-related HRI death. When the high risk industries were stratified by sex, men continued to have significantly higher rates. Population studies also find males account for the majority of deaths. The Centers for Disease Control and Prevention found that of the 7415 heat-related deaths reported 1999–2010, the majority (68%) were male [CDC, 2012]. Heat wave vulnerability studies on demographic subgroups are inconclusive and inconsistencies have been reported with regard to sex [Ellis et al., 1975; Whitman et al., 1997; Semenza et al., 1999; Stafoggia et al., 2006]. Our study and other occupational research finds a much higher rate among working men and this observation deserves further study.

Although we hypothesized that increased age would be associated with higher HRI fatality rates, the difference in rates among the age groups was not substantial. Increased age is an established risk factor for heat-related deaths and population level heat-related morbidity and mortality studies have shown this to be a significant variable [Semenza et al., 1999; Basu et al., 2005; Knowlton et al., 2009]. When we dichotomized the age groups < 55 years and ≥ 55 years, the rates were nearly identical (Table I). Our data show that only the ≥ 65 years age group had an elevated risk of a heat-related death. This smaller-than expected increase in the heat-related death rate among the oldest workers might be explained by older persons not being equally represented in the high risk occupations and duties within these high risk industries. This warrants further investigation.

Race had a small, but significant, effect on fatality rates. The slightly increased rate among black workers seen in this analysis has also been found in other occupational heat-related studies [Mirabelli and Richardson 2005; Florida DOH, 2011]. Ethnicity was more strongly associated with higher rates: Hispanics were 3.2 times more likely to die of work-related heat exposure than non-Hispanics. Although Hispanics account for 13.6% of the general workforce, they represent an estimated 20.1% of agriculture and 23.4% of construction workers. The higher risk for Hispanics is partially explained by their over-representation in these high risk industries. However, when ethnicity was stratified for the agriculture and construction industries, the higher rates persisted. As previously reported, these workers may have added risks due to language and cultural barriers; migrant worker or day laborer status; hazards of poverty; poor housing and healthcare; and inadequate training [Kahn, 2004; Kandel, 2008; Liebman and Augustave, 2010; Lowry et al., 2010; Mirabelli et al., 2010; Culp et al., 2011; Vallejos, 2011; Fleischer et al., 2013].

As expected, agriculture and construction had the highest rates for HRI deaths. Some farm and construction workers are paid by the job, and individuals may avoid breaks as it will negatively influence their income. Heat-related studies in the U.S. construction industry are particularly lacking, however, heat stress and the need for preventive measures in the farming industry have been previously discussed [Luginbuhl et al., 2008; Kjellstrom et al., 2009; Park et al., 2009; Liebman and Augustave, 2010; Lowry et al., 2010; Mirabelli et al., 2010; Vallejos, 2011; Fleischer et al., 2013; Stoeckin-Marois et al., 2013].

Our study identified 15 military personnel who expired due to environmental heat while on the job or training at a U.S. facility. The military has performed numerous studies on the health of soldiers and the effects of extreme heat, as heat exposure has historically been a military concern. Heat illness research and implementation of preventive measures are key practices of the U.S. military and discussed elsewhere [Yaglou and Minard, 1957; Gardener et al., 1996; Epstein et al., 1999; AETC, 2000; Carter et al., 2005; Hollowell, 2010].

Although Texas and California accounted for 88 (24.5%) of the fatalities, they were not among the states with the highest death rates. California, which did not have a significantly high rate (0.24), has evaluated a comprehensive heat prevention campaign (initiated in 2010) targeted at agricultural workers and has an enforceable regulation for prevention of heat illness in outdoor workers [CA Code of Regulations, 2012; Cal/OSHA, 2013]. In fact, California and Washington states are in the forefront for implementing workplace safety policies to prevent heat-related illnesses [Jackson and Rosenberg, 2010]. States with higher HRI death rates, such as Mississippi and Arkansas, should consider immediate implementation of such policies or prevention programs targeting their high risk industries and workers.

With 71% of the cases dying on the day of exposure, the survival time variable suggests that the HRI cases were acute and possibly not recognized and treated in a timely manner. Prevention programs should focus on early recognition and treatment of HRI signs and symptoms.

Length of service, which has been shown to be associated with workplace injuries, was not analyzed in this study due to lack of data. Newer employees and those not acclimatized to working in hot conditions are most likely at high risk of HRI as seen in other studies [Epstein et al., 1999; Carter et al., 2005; Maeda et al., 2006]. HRI training and acclimatization programs for new employees should be encouraged for all industries employing outdoors workers.

Many of the intervention and monitoring practices recommended in the available heat stress prevention guidances, such as the American Conference of Governmental Industrial Hygienists guideline [ACGIH, 2009], are not practical for all work places. The guidelines are appropriate for large, stable operations, with established procedures, medical surveillance, Wet Bulb Globe Temperature equipment and an industrial hygienist responsible for monitoring conditions. For worksites that are small and non-stationary, or where employees work independently or in remote areas, the use of complex guidelines may not be feasible. As noted by Yorio and Wachter [2013], small businesses may not have the resources to develop and implement effective safety measures. Small establishments that are decentralized may also lack the organizational structure to support safe practices.

These reasons may explain why the highest percentage of heat-related deaths occurred in establishments of < 10 employees. Yet, these small establishments are exempt from OSH Act’s injury and incident reporting requirement as well as programmed OSHA inspections (29 CFR 1904.1). This study, as well as previous research, has shown that work-place fatalities can be disproportionally high among small businesses [Taylor et al., 2002; Weil and Wolfrod, 2013]. Clearly these establishments should be targets for well-designed interventions to communicate, educate, and address workplace health and safety. Additionally, small businesses merit particular attention from occupational health policy makers for a strategic plan for risk communication and possibly a legislative approach on the particular health and safety needs of these establishments [MacEachen et al., 2010].

OSHA, with the support of NIOSH, launched a heat illness prevention campaign in the summer of 2011. The aim of this endeavor is to educate both employers and employees on recognition and prevention of occupational heat illness. The OSHA website provides information on risks, prevention, signs and symptoms, and first aid (https://www.osha.gov/SLTC/heatstress/index.html).

Limitations

Our data and analyses include several potential limitations which are inherent to occupational surveillance studies. Surveillance of worker illnesses and injuries is not optimal and it is well-established that occupational illnesses and injuries are undercounted [Rosenman et al., 2006; Miller, 2008; AFL-CIO, 2011]. Further, there are many reasons why employees may not report illness or injury to employers, including: 1) fear of discipline or termination; 2) economic incentives; 3) fear of being labeled as accident-prone or a problem employee; and 4) foreign-born workers may fear being reported to the U.S. Citizenship and Immigration Services [AFL-CIO, 2011]. Although these issues apply to workers reporting on-the-job illnesses and injuries, a fatality may not be classified as work-related if it occurs after an individual has completed his or her shift or leaves the job site.

The outcome - occupational heat-related fatality - is subject to disease misclassification because heat-related illnesses are not always recognized by patients, physicians or medical examiners. Definitions and procedures used by medical examiners and coroners are not standardized [Donoghue et al., 1997; Sun, 2010]. Deaths, such as cardiovascular fatalities, where heat was a contributory cause may not be recorded as heat-related, as CFOI data represent only those deaths for which heat exposure is specifically included on the death certificate or other official documentation. Heat-related occupational fatalities are expected to be underreported for purposes of this study and the number of heat-related fatalities presented should be considered the minimum estimate of deaths. Nevertheless, as determined by Layne [2004], CFOI provides the most comprehensive and complete count of fatal work injuries available.

CPS denominator estimates may have some level of sampling error that can unknowingly impact our calculated fatality rates. The rates are based on employment only and do not take into account differences in the number of hours worked [BLS/CFOI, 2006].

The results of this study are based on 359 cases and yearly average rates from an 11-year time frame. Failure to achieve significance in variable associations might reflect insufficient sample size or other study limitations rather than absence of an actual relationship [Gordis, 2009]. Additionally, the rates for the states are based on this 11-year timeframe and therefore any decreases in deaths due to implementation of heat stress programs are not captured in these data.

We analyzed industry sector only. Further analysis of occupation will provide additional characterization of HRI fatalities in the workplace. Lastly, consideration of employees' personal risk factors and predisposition to heat illnesses, as well as interactions between risk factors, was beyond the scope of this study.

Conclusions

Improving our understanding of at-risk workers is essential to avert preventable heat-related deaths and illnesses. This study is a first step in characterizing these workplace fatalities. Occupational exposures to heat may be more hazardous than routine community exposures as the individual has less control over the work environment.

Heat-related morbidity in the workplace is difficult to ascertain due to limitations in occupational surveillance systems. However, fatal and non-fatal occupational heat-related illnesses most likely have similar epidemiologic patterns and risk factors. Further research on personal risk factors, PPE use, and other potential occupational or environmental risk factors contributing to heat-related morbidity and mortality in the workplace is needed.

Although severe weather elements have always been a threat to human health, significant shifts in weather patterns are escalating and climate change is now recognized by the World Health Organization as one of the leading global health threats of the 21st century [WHO, 2009]. Research on occupation health impacts of weather extremes is relevant not only for the present, but also to contribute to preparedness for, and adaptation to, the projected effects of climate change.

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References

AFL-CIO Safety and Health Department. A national and state-by-state profile of worker safety and health in the United States. Washington, DC: American Federation of Labor & Congress of Industrial Organizations; 2011. Death on the job- the toll of neglect.

Air Education and Training Command (AETC). Prevention of Heat Stress Disorders. AETC Instruction; 2000. p. 48-101.

American Conference of Governmental Industrial Hygienists. Heat Stress and Strain. TLVs. 2009 Available at: www.acgih.org/store/.

Anderson BG, Bell ML. Heat waves in the United States: Mortality risk during heat waves and effect modification by heat wave characteristics in 43 U.S. communities. Environ Health Perspect. 2011; 119(2):210–218. [PubMed: 21084239]

Basu R, Samet JM. Relation between elevated ambient temperature and mortality: A review of the epidemiologic evidence. Epidemiol Rev. 2002; 24(2):190–202. [PubMed: 12762092]

Basu R, Dominici F, Samet JM. Temperature and mortality among the elderly in the United States - A comparison of epidemiologic methods. Epidemiology. 2005; 16(1):58–66. [PubMed: 15613946]

Bonauto D, Anderson R, Rauser E, Burke B. Occupational Heat Illness in Washington State, 1995–2005. Am J Ind Med. 2007; 50:940–950. [PubMed: 17972253]

Bonauto D, Rauser E, Lim L. Occupational health illness in Washington state, 2000–2009. Washington State Department of Labor & Statistics. 2010

Braga AL, Zanobetti A, Schwartz J. The effect of weather on respiratory and cardiovascular deaths in 12 U.S. cities. Environ Health Perspect. 2002; 110(9):859–863. [PubMed: 12204818]

Bureau of Labor Statistics (BLS). [Accessed: January 23, 2012] News. National Census of Fatal Occupational Injuries in 2001. Released September 25, 2002. Available at: http://www.bls.gov/iif/oshwc/cfoi/cfnr0008.pdf

Bureau of Labor Statistics (BLS/CFOI). [Accessed November 30, 2011] CFOI. Fatality Rates Technical Notes. 2006 Feb.. Available at http://www.bls.gov/iif/oshwc/cfoi/rate_exp.pdf

Bureau of Labor Statistics (BLS). [Accessed September 25, 2013] Handbook of Methods. Chapter 9 Occupational Safety & Health Statistics. Available at http://www.bls.gov/opub/hom/

Cal/OSHA. Heat Illness Prevention. Available at http://www.dir.ca.go/DOSH/HeatIllnessInfo.html.

California Code of Regulations. [Accessed March 20, 2012] Title 8, Section 3395. Heat Illness Prevention. Available at http://www.dir.ca.gov/title8/3395.htm.

Carter R, Cheuvront SN, Williams JO, Kolka MA, Stephenson LA, Sawka MN, Amoroso PJ. Epidemiology of hospitalizations and deaths from heat illness in soldiers. Med Sci Sports Exerc. 2005:1338–1344. [PubMed: 16118581]

Centers for Disease Control and Prevention (CDC). QuickStats: Number of Heat-related deaths by sex, National Vital Statistics System, United States, 1999–2010. Morb Mortal Wkly Rep. 2012; 61(36): 729.

Crockford GW. Protective clothing and heat stress: Introduction. Ann Occup Hyg. 1999; 43(5):287–288. [PubMed: 10481627]

Culp K, Tonelli S, Ramey SL, Donham K, Fuortes L. Preventing heat-related illness among Hispanic farm workers. Am Assoc Occup Health Nurses J. 2011; 59(1):23–32.

Curriero FC, Heiner KS, Samet JM, Zeger SL, Strug L, Patz JA. Temperature and mortality in 11 cities of the eastern United States. Am J Epidemiol. 2002; 155:80–87. [PubMed: 11772788]

Dolney TJ, Sherdian SC. The relationship between extreme heat and ambulance response calls for the City of Toronto, Ontario, Canada. Environ Res. 2006; 101:94–103. [PubMed: 16225860]

Donoghue AM. Heat illness in the U.S. mining industry. Am J Ind Med. 2004; 45:351–356. [PubMed: 15029567]

Donoghue ER, Grahan MA, Jentzen JM, Lifschultz B, Luke JL, Mirchandani HG. Criteria for the diagnosis of heat-related deaths: National Association of Medical Examiners: Position Paper. Am J Forensic Med Pathol. 1997; 18(1):11–14. [PubMed: 9095294]

Ellis FP, Nelson F, Pincus L. Mortality during heat waves in New York City July, 1972 and August and September, 1973. Environ Res. 1973; 10:1–13. [PubMed: 1175573]

Epstein Y, Moran DS, Shapiro Y, Sohar E, Shamer J. Exertional heat stroke: A case series. Med Sci Sports Exerc. 1999; 31(2):224–228. [PubMed: 10063810]

Fleischer NL, Tiensman H, Sumaitani J, Mize T, Amarnath KK, Bayakly AR, Murphy MW. Public health impact of heat-related illness among migrant farm workers. Am J Prev Med. 2013; 44(3): 1999–2006.

Florida Department of Health (DOH), Division of Environmental Health, Bureau of Environmental Public Health Medicine. Descriptive Analysis of Occupational Heat-related Illness Treated in Florida Hospitals and Emergency Departments. 2011. Available at http://www.myfloridaeh.com/newsroom/index.html

Gabriel KMA, Endlicher WR. Urban and rural mortality rates during heat waves in Berlin and Brandenburg, Germany. Environ Pollut. 2011; 159(8–9):2044–2050. [PubMed: 21295389]

Gardner JW, Kark JA, Karnei K, Sanborn JS, Gastaldo E, Burr P, Wenger CB. Risk factors predicting exertional heat illness in male Marine Corps recruits. Med Sci Sports Exerc. 1996; 28(8):939–944. [PubMed: 8871901]

Gordis, L. Epidemiology. 4th edition. Philadelphia, PA: Saunders Elsevier; 2009.

Gubernot DM, Anderson GB, Hunting KL. The epidemiology of occupational heat-related morbidity and mortality in the United States: A review of the literature and assessment of research needs in a changing climate. Internat J Biometeorol. 2013

Hajat S, Armstrong B, Baccini M, Biggeri A, Bisanti L, Russo A, Paldy A, Menne B, Kosatsky T. Impact of high temperature on mortality: Is there an added heat wave effect? Epidemiology. 2006; 17(6):632–638. [PubMed: 17003686]

Hollowell DR. Perceptions of, and reactions to, environmental heat: a brief note on issues of concern in relation to occupational health. Global Health Action. 2010; 3:5653.

Jackson LL, Rosenberg HR. Preventing heat-related illness among agricultural workers. J Agromed. 2010; 15:200–215.

Kahn, AP. The encyclopedia of work-related illnesses, injuries, and health issues. New York, NY: Facts On File, Inc.; 2004.

Kandel W. Profile of hired farm workers, a 2008 update. USDA. Economic Research Service. 2008 Report No. 60.

King, BS.; Gibbins, JD. [Accessed January 5, 2012] Centers for Disease Control and Prevention. NIOSH. Health Hazard Evaluation of Deepwater Horizon Response Workers. Health Hazard Evaluation Report HETA. 2011. 2010– 0115; 2010–0129-3138. Available at http://www.cdc.gov/niosh/hhe/reports/pdfs/2010–0115-0129–3138.pdf

Kjellstrom T, Kovats S, Lloyd SL, Holt T, Tol RSJ. The direct impact of climate change on regional labor productivity. Arch Environ Occup Health. 2009; 64(4):217–227. [PubMed: 20007118]

Knowlton K, Rotkin-Ellman M, King G, Margolis HG, Smith D, Solomon G, Trent R, English P. The 2006 California heat wave: Impacts on hospitalizations and emergency department visits. Environ Health Perspect. 2009; 117(1):61–67. [PubMed: 19165388]

Layne LA. Occupational injury mortality surveillance in the United States: An examination of census counts from two different surveillance systems, 1992–1997. Am J Ind Med. 2004; 45(1):1–13. [PubMed: 14691964]

Liebman, Ak; Augustave, W. Agricultural Heat And Safety: Incorporating The Worker Perspective. J Agromed. 2010; 15:192–199.

Lowry SJ, Blecker H, Camp J, De Castro B, Hecker S, Arbabi S, Traven N, Seixas NS. Possibilities and challenges in occupational injury surveillance of day laborers. Am J Ind Med. 2010; 53(2): 126–134. [PubMed: 19722216]

Luginbuhl RC, Jackson LL, Castillo D, Loringer KA. Heat-related deaths among crop workers – United States, 1992–2006. Morb Mortal Wkly Rep. 2008; 57(24):649–653.

MacEachen E, Kosny A, Scott-Dixon KFacey M, Chambers L, Breslin C, Kyle N, Irvin E, Mahood Q. Small Business Systematic Review Team. Workplace health understandings and processes in small businesses: A systematic review of the qualitative literature. J Occup Rehabil. 2010; 20:180–198. [PubMed: 20140483]

Maeda T, Kaneko SY, Ohta M, Tanaka K, Sasaki A, Fukushima T. Risk factors for heatstroke among Japanese forestry workers. J Occup Health. 2006; 48(4):223–229. [PubMed: 16902265]

Miller J Chair. US House of Representatives: Hidden Tragedy: Underreporting of Workplace Injuries and Illnesses, A Majority Staff Report by the Committee of Education and Labor. 2008

Mirabelli MC, Richardson DB. Heat-related fatalities in North Carolina. Am J Public Health. 2005; 95(4):635–637. [PubMed: 15798122]

Mirabelli MC, Quandt SA, Crain R, Grzywacz JG, Robinson EN, Vallejos QM, Arcury TA. Symptoms of heat illness among Latino farm workers in North Carolina. Am J Prev Med. 2010; 39(5):468–471. [PubMed: 20965386]

National Institute of Occupational Safety and Health (NIOSH). Working in hot environments. 1986 DHHS Publication No. 86–112.

National Oceanic and Atmospheric Administration (NOAA). [Ac-cessed September 22, 2011] Website. National Weather Service. Heat: a major killer. Heat Index Chart. 2011. Available at http://www.nws.noaa.gov/os/heat/index.shtml

Park EK, Hannaford-Turner K, Lee HJ. Use of personal protective equipment in agricultural workers under hot and humid conditions. Ind Health. 2009; 47:200–201. [PubMed: 19367051]

Ramsey JD. Task performance in heat: A review. Ergonomics. 1995; 38(1):154–165. [PubMed: 7875117]

Rey G, Jougla E, Fouillet A, Pavillon G, Bessemoulin P, Frayssinet P, Clavel J, Hémon D. The impact of major heat waves on all-cause and cause-specific mortality in France from 1971 to 2003. Int Arch Occup Environ Health. 2007; 80:615–626. [PubMed: 17468879]

Rothman, KJ.; Greenland, S. Modern epidemiology. 3rd edition. Philadelphia, PA: Lippincott, Williams and Wilkins; 2008.

Rosenman KD, Kalush A, Reilly MJ, Gardiner JC, Reeves M, Luo Z. How much work-related injury and illness is missed by the current national surveillance system? J Occup Environ Med. 2006; 48(4):357–365. [PubMed: 16607189]

Rowlinson S, Jia AY, Li B, Ju C. Management of climatic heat stress risk in construction: A review of practices, methodologies, and future research. Accident Analy Prev. 2013

Schwartz J, Samet JM, Patz JA. Hospital admissions for heart disease: The effects of temperature and humidity. Epidemiology. 2004; 15:755–761. [PubMed: 15475726]

Semenza JC, Rubin CH, Falter KH, Selanikio JD, Flanders WD, Howe HL, Wilhelm JL. Heat-related deaths during the July 1995 heat wave in Chicago. N Engl J Med. 1996; 335(2):84–90. [PubMed: 8649494]

Semenza JC, McCollough JE, Flanders D, McGeehin MA, Lumpkin JR. Excess hospital admissions during the July 1995 heat wave in Chicago. Am J Prev Med. 1999:269–277. [PubMed: 10493281]

Stafoggia M, Forastiere F, Agostini D, Biggeri A, Bisanti L, Cadum E, Caranci N, de' Donato F, De Lisio S, De Maria M, et al. Vulnerability to heat-related mortality: A multicity, population-based, case-crossover analysi. Epidemiology. 2006; 17(3):315–323. [PubMed: 16570026]

Stoeckin-Marois M, Hennessy-Burt T, Mitchell D, Schenker M. Heat-related illness knowledge and practices among California hired farm workers in The MICASA Study. Ind Health. 2013; 51(1): 47–55. [PubMed: 23411756]

Sun LH. Medical Examiners use differing criteria to tally heat-related deaths. Washington Post. 2010 Jul 27.

Taylor AJ, McGwin G, Valent F, Rue LW III. Fatal occupational electrocutions in the United States. Injury Prev. 2002; 8:306–312.

Vallejos QM. Migrant farm workers' housing conditions across an agricultural season in North Carolina. Am J Ind Med. 2011; 54(7):533–544. [PubMed: 21360725]

Wainwright SH, Buchanan SD, Mainzer M, Parrish RG, Sinks TH. Cardiovascular mortality—the hidden peril of heat waves. Prehospital Disaster Med. 1999; 14(4):222–231. [PubMed: 10915407]

Weil D, Wolfrod R. Work-Related Fatal and Nonfatal Injuries among U.S. Construction Workers, 1992–2008. Electronic Library of Construction Occupational Safety and Health. 2010 Available at http://www.elcosh.org.

Whitman S, Good G, Donoghue ER, Benbow N, Shou W, Mou S. Mortality in Chicago attributed to the July 1995 heat wave. Am J Public Health. 1997; 87:1515–1518. [PubMed: 9314806]

World Health Organization. Geneva: WHO; 2009. Global health risks: Mortality and burden of disease attributable to selected major risks. Available at http://www.who.int/mediacentre/factsheets/fs266/en/index.html. [Accessed November 4, 2011]

Yaglou CP, Minard D. Control of heat casualties at military training centers. Am Med Assoc Arch Ind Health. 1957; 16:302–316.

Yorio PL, Wachter JK. The impact of human performance focused safety and health management practices on injury and illness rates: Do size and industry matter? Safety Sci. 2013; 62:157–167.

Table I

Occupational Heat-Related Fatalities in the U.S. 2000–2010, by Demographic Characteristics

Characteristic	Average # of workers per year[a]	Average HRI deaths per year[b]	Average rate per million workers per year[c]	Rate ratio (95%CI)[d]	Percent of total HRI deaths[e]
Total……….	140,346,000	32.6	0.22	N/A	**100%**
Sex					
Female…………	65,482,000	0.9	0.01	1.0 (referent)	**2.8%**
Male ……………	74,864,000	31.7	0.40	**32.0 (17.0–60.0)**	**97.2%**
Age group					
16–19 years………	5,903,000	1.3	0.15	1.0 (referent)	**3.9%**
20–24 years………	13,437,000	2.4	0.12	0.8 (0.4 – 1.5) 1.2	**7.2%**
25–34 years………	30,769,000	6.2	0.19	(0.7 – 2.2)	**18.9%**
35–44 years………	34,209,000	8.9	0.26	1.7 (1.0 – 3.0)	**27.3%**
45–54 years………	32,515,000	8.5	0.25	1.6 (0.9 –2.8)	**25.9%**
55 –64 years……...	18,142,000	3.7	0.21	1.4 (0.7 – 2.5)	**11.4%**
≥ 65 years ………	5142,000	1.7	0.34	**2.2 (1.1 – 4.4)**	**5.3%**
< 55 years……..	116,833,000	27.2	0.22	1.0 (referent)	**83.3%**
≥ 55 years………	23,284,000	5.5	0.23	1.0 (0.8 – 1.3)	**16.7%**
Race					
White …………..	116,019,000	24.1	0.20	1.0 (referent)	**73.8%**
Black ……………	15,254,000	4.7	0.29	**1.5 (1.1 – 2.0)**	**13.6%**
Asian ……………	6,368,000	1.0	0.16	0.8 (0.4 – 1.4)	**3.1%**
Other ……………	N/A	1.8	N/A		**5.6%**
Not reported ……	N/A	1.0	N/A		**3.1%**
Ethnicity					
Non–Hispanic…….	**121,951,000**	**22.0**	**0.17**	**1.0 (referent)**	**67.4%**
Hispanic …………	**18,395,000**	**10.3**	**0.54**	3.2 (2.5 – 4.0)	**31.5%**
Not Reported…….	**N/A**	**N/A**[f]	**N/A**		

CI – Confidence Interval; **HRI**- Heat-related illness

[a]All numbers may not sum to total due to CPS rounding of estimates. Does not include military personnel and volunteers.

[b]Includes military personnel and volunteers

[c]Excludes military personnel and volunteers

[d]Bolded values are statistically significant

[e]May not total 100% due to rounding

[f]Below BLS publishing criteria

Table II

Occupational Heat-Related Fatality Rates in the U.S., 2000–2010, by Industry

Industry	NAICS code[a]	Average Yearly workers	Average yearly HRI deaths	Average rate per million workers/year	Rate ratio (95% CI)	Percent of all industry sector HRI deaths[b]
Agriculture, Forestry, Fishing, and Hunting	11	2,232,000	6.8	3.06	35.2 (26.3–47.0)	21.0%
Construction	23	10,503,000	12.0	1.13	13.0 (10.1–16.7)	36.8%
Support, Waste, and Remediation Services	56	5,846,000	3.3	0.56	6.4 (4.4 9.4)	10.0%
All other industries	--	121,775,000	10.5	0.09	1.0 (referent)	32.3%

CI – Confidential Interval; **HRI** - Heat-related illness

[a] North American Industrial Classification System

[b] Numbers may not sum to 100% due to rounding

Table III

Ten U.S. States with Highest Occupational Heat-Related Death Rates for 2000–2010

Rank by Rate	State	Average # of workers per year	Average HRI deaths per year[a]	Average rate per million workers per year[b]	Rate Ratio (95% CI)	Percent of all national HRI deaths that occurred in state[c]
1	Mississippi	1,212,000	1.3	1.05	6.4 (3.7–10.9)	3.9%
2	Arkansas	1,241,000	0.8	0.66	4.0 (2.1–7.8)	2.5%
3	Nevada	1,150,000	0.7	0.63	3.8 (1.9–7.7)	2.2%
4	West Virginia	757,000	0.5	0.60	3.6 (1.5 –8.8)	1.4%
5	South Carolina	1,913,000	1.1	0.52	3.1 (1.8–5.6)	3.3%
6	North Carolina	4,093,000	2.0	0.47	2.8 (1.8 –4.4)	6.1%
7	Arizona	2,687,000	1.2	0.41	2.5 (1.4–5.1)	3.6%
8	Oklahoma	1,632,000	0.6	0.40	2.4 (1.1 –5.1)	1.9%
9	Florida	8,118,000	3.7	0.37	2.2 (1.6–3.1)	11.4%
10	Missouri	2,755,000	1.0	0.36	2.2 (1.2–4.0)	3.1%
	All other 40 states + DC	114,442,000	19.7	0.17	1.0 (referent)	60.0%

[a] Includes military personnel and volunteers

[b] Excludes military personnel and volunteers

[c] May not equal 100% due to rounding