Title

Risk factors for hyperthermia mortality among emergency department patients

Authors
Hall, Carlisha
Ha, Sandie
Yen, Irene H
et al.

Publication Date
2021-12-01

DOI
10.1016/j.annepidem.2021.09.009

Peer reviewed

Manuscript title: Risk factors for hyperthermia mortality among emergency department patients

Authors: Carlisha Hall, B.S.*; Sandie Ha, Ph.D., M.P.H.; Irene H. Yen, Ph.D., M.P.H.; Sidra Goldman-Mellor, Ph.D., M.P.H

Department of Public Health; School of Social Sciences, Humanities, and Arts; University of California, Merced; Merced CA 95343, USA. Email address: chall24@ucmerced.edu;; sha55@ucmerced.edu; iyen@ucmerced.edu; sgoldman-mellor@ucmerced.edu

*Corresponding author:

Carlisha Hall, B.S.
Department of Public Health
School of Social Sciences, Humanities, and Arts
University of California, Merced; Merced, CA 95343, USA
(209) 228-2498
chall24@ucmerced.edu

Running head: Risk factors for hyperthermia

Acknowledgments

This project was funded through the University of California Firearm Violence Research Center and through National Institute of Mental Health grant R15 MH113108-01. The sponsors had no role in the study design; collection, analysis, or interpretation of data; writing of the report, or decision to submit the article for publication.

Manuscript word count: 3,186
Pages: 19
Tables: 4

Abstract

Purpose: This study examines risk factors for heat-related mortality due to hyperthermia in emergency department patients, a vulnerable population.

Methods: This matched case-control study used statewide, longitudinally linked emergency department (ED) data and death records from California. Cases comprised California residents (≥18 years) who presented to a state-licensed ED and died of hyperthermia during the study period (2009-2012). For each case, up to five ED patients were randomly selected as live controls and matched on sex and age. Patients' demographic characteristics and history of ED utilization for alcohol use, drug use, psychiatric disorders, heart-related conditions, chronic respiratory disease, neurodegenerative disorders, and cerebrovascular disease were assessed in relationship to hyperthermia mortality.

Results: Using multivariate conditional logistic regression models, hyperthermia mortality cases had higher odds of prior ED utilization for alcohol use (OR=11.16, 95% CI=3.87, 32.17) compared to controls. Cases were also more likely than controls to have Medicare insurance (OR=5.80, 95% CI=1.70, 15.15) or self-pay (OR=5.39, 95% CI=1.73, 16.79), at their most recent ED visit.

Conclusions: ED patients presenting with alcohol problems may face increased risk of hyperthermia mortality. To help reduce heat-related mortality, EDs should consider interventions that target patients vulnerable to heat exposure.

Keywords: Hyperthermia; emergency department; alcohol; heat

Heat-related mortality, although highly preventable, is expected to become an increasingly pressing public health threat due to climate change. Since the late nineteenth century, the earth's surface temperature has experienced an average increase of roughly 1.62°F (0.9°C).[1] Climate projections suggest the U.S. will experience substantial increases in summer temperatures and extreme heat waves in the years to come.[2,3] This will be compounded by increases in the likelihood of power outages, resulting from overloaded electrical grids, that disable air conditioners and other sources of cooling[4]. Expanding our understanding of risk factors for heat-related mortality is necessary to support important public health prevention efforts as the climate warms.

Structurally vulnerable populations may be at particularly high risk for heat-related mortality as temperatures increase.[5] During periods of extreme heat, contextual factors such as social isolation, insufficient access to medical care, residence in an urban area with limited greenspace, and lack of climate-controlled housing may increase individuals' vulnerability to heat-related mortality.[5] In the U.S., these risk factors are more likely to be concentrated among people of minoritized race/ethnicity and those with low income.[5] Chronic diseases such as kidney disease, diabetes, and cardiovascular disease are also associated with heat-related mortality, and may be more prevalent among racial/ethnic minority groups.[5]

Outcome measures for heat-related mortality vary. Prolonged heat exposure typically increases risk of heat-related mortality through multisystem organ dysfunction or by worsening preexisting medical conditions (including cardiovascular disease, nervous system disorders, respiratory diseases, kidney diseases, and psychiatric and substance use disorders).[6–9] Therefore, most prior studies have measured heat-related mortality as all-cause mortality or cause-specific mortality that occurs in conjunction with high temperatures or heatwaves.[8,10–14] The underlying physiological cause of heat-related mortality, however, is hyperthermia injury, a condition characterized by thermoregulatory dysfunction and an abnormal increase in core body temperature (>40 °C).[9,15] Hyperthermia mortality has been under-utilized as a measure of heat-related mortality because hyperthermia deaths are underreported and misclassified as deaths due to other conditions.[13] However, hyperthermia mortality can occur during non-heatwave periods and may occur more frequently as climate change persists, and is increasingly considered the appropriate operational definition of heat-related mortality.[16]

Prior clinical evidence suggests risk factors for hyperthermia morbidity include age, preexisting health conditions and/or adverse health behaviors. As a consequence of aging, physiologic heat-adaptation and thermoregulation declines, increasing risk of hyperthermia injury.[9,15] Health conditions that induce fevers, inhibit sweat production, or reduce adaptability to heat-related stress (e.g., infections, psychological disorders, cardiovascular disorders, skin disorders) may predispose individuals to overheating.[6,9] Cognitive processing and behavioral responses to heat discomfort, such as increasing fluid intake, wearing appropriate clothing, or seeking heat-alleviating resources, can be impaired by various psychiatric and neurological disorders.[6] Illicit drugs, alcohol, and various medications (e.g., antipsychotics, antidepressants, anticholinergic agents, tranquilizers) may also increase risk of hyperthermia injury by suppressing thermoregulation and inducing dehydration.[15,17–23]

The current case-control study examines a range of clinical risk factors (alcohol problems, drug use, psychiatric disorders, heart-related conditions, chronic respiratory/lung disease, neurodegenerative disorders, and cerebrovascular disease) for hyperthermia-related mortality among emergency department (ED) patients in California. We focus on ED patients because EDs serve a wide range of the general U.S. population, yet medically and socially vulnerable individuals (such as those in historically underserved populations and those with Medicaid or no insurance) are more likely than their less-vulnerable counterparts to utilize emergency departments (EDs) at high rates.[24,25] Thus, EDs may be well-positioned to target potentially high-risk patients for interventions, which could help reduce heat-related mortality.

Methods

Data

We obtained ED visits data from the California Office of Statewide Health Planning and Development (OSHPD) for the period January 1, 2009, through December 31, 2012. OSHPD provided de-identified information on all residents who presented to a California-licensed hospital facility during the study period. We obtained de-identified death record data containing the date and underlying cause-of-death from the California Department of Public Health Vital Records office. Death records were linked to patient hospital records by patient's social security number, sex, date of birth, race/ethnicity, and zip code of residence. This study was approved by the Institutional Review Boards of the California Health and Human Services Agency and the University of California, Merced.

Study Design and Case-Control Definitions

The current study uses a matched case-control study design of ED patients who presented to a California-licensed ED between January 1, 2009 and December 31, 2012. Cases included all decedents aged ≥ 18 years who made at least one ED visit and died during the study period from hyperthermia (exposure to excessive natural heat, defined by the underlying cause-of-death International Classification of Diseases, Tenth Revision (ICD-10) code X30).[26] For each case, up to five living controls were randomly selected from the population of patients presenting to the ED within one day of the case's death, matched on sex and age (± two years). A unique patient identifier (encrypted SSN) was used to follow back cases and controls retrospectively across any ED visit made prior to the index date. The index date was defined, for each case, as the date of death. For each control, the index date was defined as the date of the ED visit that was matched to his or her case's date of death. Potential controls whose index visit culminated in death were excluded from analysis.

Measures

To assess risk factors associated with hyperthermia-related deaths, patients' diagnostic histories as assessed at their prior ED visits were examined. The period of assessment included ED visits that were made between January 1, 2009 (the earliest data available to us) and the patients' respective index dates. Health-related risk factors of interest included prior ED visits for the following diagnoses: alcohol problems, drug use, psychiatric disorders, heart-related conditions, chronic respiratory or lung disease, neurodegenerative disorders, and cerebrovascular disease. All medical conditions and behaviors were defined according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes shown in **Supplemental Table 1.** The conditions selected for this study were informed by previous findings suggesting individuals with these conditions are particularly vulnerable to excessive heat exposure.[6,10,12,13,15,16,20–23,27] Some evidence suggests that having heatstroke, a form of hyperthermia, in the past may increase risk for subsequent heat-related injuries.[28] However, none of the cases or controls in our study had a prior ED visit for heatstroke or any other clinically diagnosed heat-related illness (e.g., heat edema, heat cramps, heat syncope, or heat exhaustion). Additional risk factors of interest included patient race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, Asian/Pacific Islander, or other) and medical insurance status (private, Medicaid, Medicare, or self-pay/other), both assessed at the index visit.

Statistical Analysis

First, we conducted conditional logistic regression models to estimate odds ratios (ORs) and 95% confidence intervals (CI) for each diagnostic risk factor, additionally controlling for age to address any residual age confounding (**Model 1**). ORs were used to estimate how odds of having a history of ED utilization for alcohol problems, drug use, psychiatric disorders, heart-related conditions, chronic respiratory/lung disease, neurodegenerative disorders or cerebrovascular disease were associated with case vs. control status. We then performed a partially adjusted multivariate analysis using conditional logistic regression, controlling for age, patient race/ethnicity (ref non-Hispanic White) and insurance status (ref private insurance) as potential confounders (**Model 2**). Lastly, we conducted a fully adjusted multivariate analysis, which controlled for all visit history variables as well as the sociodemographic factors (**Model 3**). All analyses were performed using Stata 14.0 (StataCorp LP, College Station, TX) statistical software.

Results

Demographic characteristics for cases and controls are shown in (**Table 1**). The matched case-control analysis included 78 cases and 385 controls. The mean age for hyperthermia mortality cases was 56 years (age range 22-93), and the mean age for controls was 55 years old (age range 18-94). Males accounted for approximately three-quarters of cases and their matched controls (cases: n=59, 76%; controls: n=270, 70%). The majority of both cases and controls were non-Hispanic White patients (cases: n=46, 59%; controls n=217, 56%). Cases most frequently received health insurance through Medicare (n=25, 32%) or Medicaid (n=15, 19%), while controls most frequently had private health insurance (n=151, 39%). Of the 78 heat death cases, 20 individuals were admitted to the ED and died on the date of their admission to the ED. Most heat deaths (95%) occurred during warm months (May-September).

High proportions of hyperthermia death cases had a history of ED visits for heart-related conditions (37%), alcohol use (32%), and psychiatric disorders (31%) (**Table 2**). In model 1, compared to controls, hyperthermia death cases had significantly higher odds of an ED utilization history for alcohol problems compared to controls (OR=5.35, 95% CI=2.56, 11.17, **Table 3**, model 1). Results from the model 1 analyses also show that cases were more likely than controls to self-pay (OR=4.56, 95% CI=1.70, 12.19) or have Medicare (OR= 3.94, 95% CI=1.54, 10.15) or other/unknown insurance types (OR=5.08, 95% CI=1.67, 15.46) rather than private health insurance When controlling for race/ethnicity and insurance status in the partially adjusted multivariate analyses of each visit history variable (**Table 3,** model 2), hyperthermia death cases were more likely to have a history of ED utilization for alcohol problems compared to controls.

After controlling for all visit history variables, race/ethnicity, and insurance status, prior ED visits for alcohol problems remained significantly associated with odds of being a case (OR=11.15, 95% CI=3.87, 32.17) (**Table 3,** model 3). No other visit history variables were significantly associated with the likelihood of being a hyperthermia mortality case. In model 3, the likelihood of cases using self-pay (OR=5.39, 95% CI=1.73, 16.79), Medicare (OR=5.80, 95% CI=1.70, 15.15) or other/unknown payment sources (OR=7.36, 95% CI=1.80, 29.95) at the time of their index visit were statistically significantly higher compared to controls (**Table 3**). Race/ethnicity was not associated with case/control status.

Discussion

Results from our study suggest that, among ED patients, prior ED utilization for alcohol-related problems was associated with increased likelihood of heat-related mortality due specifically to hyperthermia. Hyperthermia decedents were also more likely to have used public insurance or to self-pay at their last observed ED visit when compared to controls. We did not find any association between hyperthermia mortality and patient histories for drug use, psychiatric disorders, heart-related conditions, chronic respiratory/lung disease, neurodegenerative disorders, or cerebrovascular disease.

Our main study finding is consistent with other reports and studies suggesting that persons with a history of alcohol problems may be particularly vulnerable to heat-related mortality.[16,20–23,29] Alcohol may act as a poikilothermic drug, altering neurotransmitters or hypothalamic regulation processes responsible for maintaining normal core body temperatures.[22] By increasing perspiration, alcohol lowers body temperature; however, alcohol also increases fluid loss and excessive dehydration, contributing to risk of hyperthermia.[16,20] Vaidyanathan et al.[16] found that alcohol poisoning was a contributing cause to several heat-related deaths. In an ethnographic study of the 1995 Chicago heat wave, neighbors reported decedents to be alcoholics or heavy drinkers, factors that were not discussed in the initial case-control study.[21] To help reduce effects of extreme heat, behavioral health treatment facilities should consider establishing heat safety plans for clients with alcohol problems during warm periods.[20]

While not statistically significant due to a small sample size, there was some indication that ED visits for cerebrovascular disease, psychiatric disorders and neurodegenerative disorders were associated with marginally higher odds of being a hyperthermia case mortality. Cerebrovascular mortality or morbidity is known to be associated with heat mortality, particularly among older adults.[30–33] Cognitive or behavioral impairments from psychiatric or neurodegenerative disorders can increase risk of hyperthermia by altering appropriate responses to heat discomfort (e.g., staying hydrated, wearing appropriate clothing, and reducing strenuous activities).[6] Antipsychotic medications are also associated with hyperthermia injury.[20,23] If larger studies with greater statistical power also observe this association, heat-related interventions for high-risk patients (e.g., educating them on the importance of keeping cool during hot periods by using an air conditioner if accessible, wearing appropriate clothing or retreating to cooler environments) should be considered.[20]

Previous studies suggest individuals with cardiovascular disease are considered high risk for heat-related mortality. [12,13,34] In our study, among ED patients, an ED utilization history for cardiovascular disease was not significantly associated with hyperthermia mortality in any model. A case-control study of heat-related mortality during heatwaves in Chicago found that people who died of heart disease had more preexisting comorbidities than those who did not die of heart disease.[12] It is possible that we lacked statistical power to detect this association, but cardiovascular diagnoses were the most common diagnoses at prior ED visits in our study population.

Our findings are consistent with research indicating that structurally vulnerable groups are particularly susceptible to heat exposure. We found that using non-private health insurance status at the index ED visit – an indicator of socioeconomic vulnerability – was associated with substantially increased odds of hyperthermia death. Patients who use Medicaid, self-pay, or have other/unknown insurance types may be more structurally vulnerable than patients with private health insurance. Adaptive health behavior modifications to reduce risk of heat-related mortality include using air conditioning, staying hydrated, wearing appropriate clothing, and reducing strenuous activities during hot days, but these strategies may be less feasible for individuals living in poverty, experiencing homelessness, or whose jobs entail outdoor activity, protective clothing, and inadequate access to hydration (e.g., farmworkers).[35] Although in this study race/ethnicity (an indicator of structural vulnerability) was not associated with the likelihood of dying from hyperthermia, heat-related intervention strategies should include tailored messages that consider cultural and economic characteristics because minoritized racial/ethnic groups are disproportionally affected by social challenges and heat exposure.[35]

Most studies in the U.S. have relied on other sources of information (e.g., autopsy reports, family members, neighbors, or friends) to assess risk factors for heat-related mortality, whereas our study utilized ED visit histories for various somatic and behavioral health conditions. Additionally, heat-related mortality is often measured using various causes of death during hot periods (or heatwaves). This is one of the first studies that measures risk factors heat-related mortality as hyperthermia among emergency department patients. The findings from this study indicate that persons with alcohol-related disorders may be predisposed to dying of overheating.

Limitations and Strengths

Our study has several limitations. Data for this study do not include deaths that occurred outside of California. Controls consisted of ED patients, which may introduce Berkson's bias. The selected controls may be relatively unhealthy in comparison to the general population, increasing the likelihood of being admitted to the ED for morbidities that are heat-related, given that controls were matched to cases on the basis of time (i.e., presenting to the ED within one day of the case's death). The effect of using these ED patient controls would likely bias our results towards the null, making our estimates more conservative.

Due to data availability, our analyses were restricted to 2009-2012 and may not generalize to more recent years. There have been changes since the study period in ED utilization rates[25] and ED clinical practice,[36] and these shifts could influence the associations observed in our study. Furthermore, the incidence of alcohol problems has increased substantially since our study period, as has the frequency of heat waves and average daily temperatures.[37,38] Despite policy changes such as the Affordable Care Act, which increased opportunities for treatment among those with behavioral health problems, the growing burdens of alcohol misuse and excess heat may interact to result in higher population risk of heat-related deaths.

In addition, due to limitations of the administrative dataset, we were also unable to assess additional measures known to increase risk of heat vulnerability, including access to air conditioning, educational status in relation to heat exposure, and social isolation. Our use of encrypted SSNs for longitudinally linking ED records to death records excludes immigrants without legal status. The exclusion of immigrants without SSNs may contribute to a reduced sample size of Latino and Asian subpopulations, and consequently affect our understanding of heat mortality on these racial/ethnic groups. Our study was also limited by the lack of data on homelessness and other important social risk factors, which may confound the associations between the observable clinical characteristics and study outcome.

ED diagnoses and death classifications are subject to misclassification and may result in undercounting hyperthermia cases and risk factors. Our strict case definition enabled us to examine deaths strictly arising from hyperthermia, but restricted our sample size, which limited the statistical power of this study. Additionally, the death certificate data used for this study did not include information on contributing factors to the underlying cause of death.

Despite these limitations, our study also has important strengths. Studies from other countries and the U.S. have used ED visits or hospitalizations with mortality data to examine risk factors for heat-related mortality, which is typically defined as all-cause mortality or cause-specific mortality occurring solely during heat wave events. However, to our knowledge, our study is the first study to use death records longitudinally linked to ED visits to examine risk factors for ICD-10-defined hyperthermia mortality, regardless of environmental heat exposure. With average U.S. temperatures rising due to climate change,[1] this represents an important contribution to the literature. An important strength of this study includes the multiple years of ED data available for examining risk factors for hyperthermia and the significant diversity in California's study population and climate zones. While most medical examiners accurately diagnose heat-related mortality, the criteria used to determine heat-related mortality varies by state and has led to the underreporting or misclassification of hyperthermia as the underlying cause of death.[13] Thus, our study is one of few to assess risk factors for a relatively large sample size of cases meeting the strict criteria for hyperthermia mortality.

Conclusion

Heat-related mortality is highly preventable, and EDs can help reduce heat-related mortality by targeting high-risk patients for interventions. Those with a medical history of alcohol-related problems should be considered high risk for heat-related mortality and may benefit from heat-related prevention strategies. ED providers may want to provide verbal warnings and resources to at-risk patients, explaining their elevated risk during summer months. Additionally, EDs may want to coordinate with shelters and homeless services to assist those socially and medically vulnerable to heat exposure.

References

1. Climate Change: How do we know. Accessed March 21, 2021. https://climate.nasa.gov/evidence/
2. CDC Temperature Extremes. Accessed March 21, 2021. https://www.cdc.gov/climateandhealth/effects/temperature_extremes.htm
3. The Effects of Climate Change. Accessed March 21, 2021. https://climate.nasa.gov/effects/
4. Stone B, Mallen E, Rajput M, et al. Compound Climate and Infrastructure Events: How Electrical Grid Failure Alters Heat Wave Risk. *Cite This: Environ Sci Technol*. 2021;55:6957-6964. doi:10.1021/acs.est.1c00024
5. Kravchenko J, Abernethy AP, Fawzy M, Lyerly HK. Minimization of heatwave morbidity and mortality. *American Journal of Preventive Medicine*. 2013;44(3):274-282. doi:10.1016/j.amepre.2012.11.015
6. Hansen A, Bi P, Nitschke M, Ryan P, Pisaniello D, Tucker G. The effect of heat waves on mental health in a temperate Australian City. *Environmental Health Perspectives*. 2008;116(10):1369-1375. doi:10.1289/ehp.11339
7. Hansen AL, Bi P, Ryan P, Nitschke M, Pisaniello D, Tucker G. The effect of heat waves on hospital admissions for renal disease in a temperate city of Australia. *International Journal of Epidemiology*. 2008;37(6):1359-1365. doi:10.1093/ije/dyn165
8. Basu R. High ambient temperature and mortality: A review of epidemiologic studies from 2001 to 2008. *Environmental Health: A Global Access Science Source*. 2009;8(1):40. doi:10.1186/1476-069X-8-40
9. Leon LR, Bouchama A. Heat Stroke. In: *Comprehensive Physiology*. Vol 5. John Wiley & Sons, Inc.; 2015:611-647. doi:10.1002/cphy.c140017
10. Azhar GS, Mavalankar D, Nori-Sarma A, et al. Heat-Related Mortality in India: Excess All-Cause Mortality Associated with the 2010 Ahmedabad Heat Wave. Akiba S, ed. *PLoS ONE*. 2014;9(3):e91831. doi:10.1371/journal.pone.0091831
11. Hoffmann B, Hertel S, Boes T, Weiland D, Jöckel K. Increased Cause-Specific Mortality Associated with 2003 Heat Wave in Essen, Germany. *Journal of Toxicology and Environmental Health, Part A*. 2008;71(11-12):759-765. doi:10.1080/15287390801985539
12. Naughton MP, Henderson A, Mirabelli MC, et al. Heat-related mortality during a 1999 heat wave in Chicago. *American Journal of Preventive Medicine*. 2002;22(4):221-227. doi:10.1016/S0749-3797(02)00421-X
13. Basu R. Relation between Elevated Ambient Temperature and Mortality: A Review of the Epidemiologic Evidence. *Epidemiologic Reviews*. 2002;24(2):190-202. doi:10.1093/epirev/mxf007

14. Vandentorren S, Suzan F, Medina S, et al. Mortality in 13 French cities during the August 2003 heat wave. *American Journal of Public Health*. 2004;94(9):1518-1520. doi:10.2105/AJPH.94.9.1518
15. Leiva DF, Church B. *Heat Illness*. StatPearls Publishing; 2021. Accessed March 21, 2021. http://www.ncbi.nlm.nih.gov/pubmed/31971756
16. Vaidyanathan A, Malilay J, Schramm P, Saha S. Heat-Related Deaths — United States, 2004–2018. *MMWR Morbidity and Mortality Weekly Report*. 2020;69(24):729-734. doi:10.15585/mmwr.mm6924a1
17. Hayes BD, Martinez JP, Barrueto F. Drug-induced hyperthermic syndromes. Part I. Hyperthermia in overdose. *Emergency Medicine Clinics of North America*. 2013;31(4):1019-1033. doi:10.1016/j.emc.2013.07.004
18. Marzuk PM, Tardiff K, Leon AC, et al. Ambient temperature and mortality from unintentional cocaine overdose. *Journal of the American Medical Association*. 1998;279(22):1795-1800. doi:10.1001/jama.279.22.1795
19. Luber G, McGeehin M. Climate Change and Extreme Heat Events. *American Journal of Preventive Medicine*. 2008;35(5):429-435. doi:10.1016/j.amepre.2008.08.021
20. Cusack L, de Crespigny C, Athanasos P. Heatwaves and their impact on people with alcohol, drug and mental health conditions: A discussion paper on clinical practice considerations. *Journal of Advanced Nursing*. 2011;67(4):915-922. doi:10.1111/j.1365-2648.2010.05551.x
21. Duneier Mitchell. Ethnography, the Ecological Fallacy, and the 1995 Chicago Heat Wave on JSTOR. Accessed March 21, 2021. https://www.jstor.org/stable/30039015?seq=1
22. Kortelainen ML. Hyperthermia deaths in Finland in 1970-86. *American Journal of Forensic Medicine and Pathology*. 1991;12(2):115-118. doi:10.1097/00000433-199106000-00006
23. Glazer JL. *The Author*. Vol 71.; 2005. Accessed March 21, 2021. www.aafp.org/afp
24. Greenwood-Ericksen MB, Kocher K. Trends in Emergency Department Use by Rural and Urban Populations in the United States. *JAMA network open*. 2019;2(4):e191919. doi:10.1001/jamanetworkopen.2019.1919
25. Tang N, Stein J, Hsia RY, Maselli JH, Gonzales R. Trends and characteristics of US emergency department visits, 1997-2007. *JAMA - Journal of the American Medical Association*. 2010;304(6):664-670. doi:10.1001/jama.2010.1112
26. U.S. EPA. Technical documentation. Accessed March 21, 2021. https://www.epa.gov/sites/production/files/2017-01/documents/heat-deaths_documentation.pdf
27. Kortelainen M-L, Kortelainen R. *Drugs and Alcohol in Hypothermia and Hyperthermia Related Deaths: A Retrospective Study "Drugs and Alcohol in Hypothermia and Hyperthermla Re-Lated Deaths: A Retrospectlve Study*. Vol 32.; 1987. Accessed April 24, 2021. www.astm.org
28. Heat Stroke (Hyperthermia) - Harvard Health. Accessed March 21, 2021. https://www.health.harvard.edu/a_to_z/heat-stroke-hyperthermia-a-to-z
29. Kilbourne EM, Choi K, Jones TS, Thacker SB. Risk Factors for Heatstroke: A Case-Control Study. *JAMA: The Journal of the American Medical Association*. 1982;247(24):3332-3336. doi:10.1001/jama.1982.03320490030031
30. Increased mortality associated with extreme heat. Accessed April 25, 2021. httpl://link.springer.com/content/pdf/10.1007/s00484-015-1007-9.pdf
31. Huang W, Kan H, Kovats S. The impact of the 2003 heat wave on mortality in Shanghai, China. *Science of the Total Environment*. 2010;408(11):2418-2420. doi:10.1016/j.scitotenv.2010.02.009

32. D'ippoliti D, Michelozzi P, Marino C, et al. *Open Access RESEARCH The Impact of Heat Waves on Mortality in 9 European Cities: Results from the EuroHEAT Project*.; 2010. Accessed April 25, 2021. http://www.ehjournal.net/content/9/1/37

33. Rooney C, Mcmichael AJ, Kovats S, Coleman MP. Excess mortality in England and Wales, and in Greater London, during the 1995 heatwave. *J Epidemiol Community Health*. 1998;52:482-486. doi:10.1136/jech.52.8.482

34. Semenza JC, Rubin CH, Falter KH, et al. Heat-Related Deaths during the July 1995 Heat Wave in Chicago. *New England Journal of Medicine*. 1996;335(2):84-90. doi:10.1056/nejm199607113350203

35. Sampson NR, Gronlund CJ, Buxton MA, et al. Staying cool in a changing climate: Reaching vulnerable populations during heat events. *Global Environmental Change*. 2013;23(2):475-484. doi:10.1016/j.gloenvcha.2012.12.011

36. Laiteerapong N, Huang ES. The pace of change in medical practice and health policy: collision or coexistence?. J Gen Intern Med. 2015;30(6):848-852. doi:10.1007/s11606-015-3182-00

37. Grucza RA, Sher KJ, Kerr WC, et al. Trends in Adult Alcohol Use and Binge Drinking in the Early 21st-Century United States: A Meta-Analysis of 6 National Survey Series. Alcohol Clin Exp Res. 2018;42(10):1939-1950. doi:10.1111/acer.13859

38. Spillane S, Shiels MS, Best AF, et al. Trends in Alcohol-Induced Deaths in the United States, 2000-2016. JAMA Netw Open. 2020;3(2):e1921451. Published 2020 Feb 5. doi:10.1001/jamanetworkopen.2019.21451

TABLES

Table 1. Demographic characteristics of hyperthermia case patients and matched controls

	Cases (n=78) N(%)/mean(SD)	Matched Controls (n=385) N (%)/mean(SD)
Sex		
Male	59 (76%)	270 (70%)
Female	19 (24%)	115 (29%)
Age (mean (SD))	56.2 (18.4	55.3 (18.5)
Race/Ethnicity		
Non-Hispanic White	46 (59%)	217 (56%)
Non-Hispanic Black	4 (5%)	40 (10%)
Hispanic	16 (21%)	92 (24%)
Asian or Pacific Islander	2 (6%)	23 (6%)
Other	6 (8%)	13 (3%)
Missing	4 (5%)	0 (0%)
Insurance Status		
Self-Payer	13 (17%)	51 (13%)
Private	13 (17%)	151 (39%)
Medicare	25 (32%)	97 (25%)
Medicaid	15 (19%)	69 (18%)
Other/Unknown	7 (9%)	16 (4%)
Missing[a]	5 (6%)	1 (0%)

Table 2. Emergency department utilization among cases and controls prior to the index visit.

ED visit history variables	Cases (n=78) N (%)	Controls (n=385) N (%)
Alcohol use disorder	25 (32)	35 (9)
Drug use disorders	13 (17)	56 (15)
Psychiatric disorders	24 (31)	95 (25)
Cardiovascular conditions	29 (37)	116 (30)
Respiratory or lung disease	11 (14)	63 (17)
Neurodegenerative disorder	7 (9)	26 (7)
Cerebrovascular disease	4 (5)	16 (4)

Table 3. Crude ORs and adjusted odds ratios (ORs) of risk factors for heat-related mortality.

Risk factors	Model 1[a] OR (95% CI)	Model 2[b] OR (95% CI)	Model 3[c] OR (95% CI)
Age	…	…	**2.94 (1.99, 4.35)**
Patient history of visit(s) with diagnosis for specified condition			
Alcohol use disorders	**5.35 (2.56, 11.17)**	**9.23 (3.62, 23.50)**	**11.15 (3.87, 32.17)**
Drug use disorders	0.99 (0.46, 2.17)	1.25 (0.50, 3.09)	0.45 (0.14, 1.54)
Psychiatric disorder	1.20 (0.66, 2.17)	1.68 (0.85, 3.33)	1.35 (0.57, 3.19)
Cardiovascular conditions	1.37 (0.76, 2.46)	1.56 (0.78, 3.11)	1.06 (0.45, 2.52)
Respiratory or lung disease	0.82 (0.38, 1.78)	0.85 (0.36, 2.00)	0.74 (0.29, 1.87)
Neurodegenerative disorder	1.51 (0.57, 4.01)	2.02 (0.66, 6.19)	2.02 (0.63, 6.47)
Cerebrovascular disease	1.69 (0.51, 5.58)	2.00 (0.57, 7.07)	2.22 (0.49, 9.99)
Race/ethnicity			
Non-Hispanic White	1.00	…	1.00
Non-Hispanic Black	0.48 (0.15, 1.53)	…	0.41 (0.10, 1.69)
Hispanic	0.99 (0.50, 1.96)	…	1.04 (0.48, 2.27)
Non-Hispanic Asian/Pacific Islander	0.36 (0.06, 2.01)	…	0.73 (0.13, 4.06)
Non-Hispanic other	2.13 (0.70, 6.55)	…	3.36 (0.95, 11.94)
Insurance Status			
Private	1.00	…	1.00
Self-Payer	**4.56 (1.70, 12.19)**	…	**5.39 (1.73, 16.79)**
Medicare	**3.94 (1.54, 10.15)**	…	**5.08 (1.70, 15.15)**
Medicaid	2.05 (0.81, 5.21)	…	1.67 (0.56, 5.04)
Other/Unknown	**6.35 (1.92, 21.02)**	…	**7.36 (1.80, 29.95)**

[a] Adjusted for age. [b]Adjusted for age, race/ethnicity and insurance status. [c]Adjusted for age, race/ethnicity, insurance status, and all other visit history variables.
Abbreviations: OR, Odds ratio. 95% CI, 95% confidence interval.
Bold font indicates statistical significance (95% CI excludes the null).

Supplemental Table 1. ICD-9 codes used to define the patient emergency department (ED) utilization history variables.

ED utilization history variable	**Corresponding ICD-9 codes**
Alcohol use disorders	291, 303, 305.0, 357.5, 425.5, 535.3, 571.0, 571.1, 571.2, 571.3, 760.71, 790.3, V79.1, V11.3
Drug use disorders	292, 304, 305.2, 305.3, 305.4, 305.5, 305.7, 305.8, 305.9, 648.3, 655.5, 760.72, 760.73, 760.75, 779.5, 965, V65.42, 305.1
Psychiatric disorders	293.81, 293.82, 295, 297, 298, 293.83, 296, 300.4, 311, 293.84, 300.00, 300.10, 300.2, 300.3, 300.5, 300.89, 300.9, 308, 309.81, 312, 313.81, 314, 312.30, 312.31, 312.32, 312.33, 312.34, 312.35, 312.39, 293.89, 293.9, 294.9, 294.8, 301, 307.1, 307.5, 307.2, 333.3, 307.3, 307.4, 307.80, 307.89, 307.9, 309, 309.21, 316, E950.0-E95.9, V62.84, E850-E858, E860-E869, E980, E981, E982, V11.0, V11.1, V11.2, V11.4, V11.8, V11.9, V70.1, V79.0, 648.4, V40.2
Cardiovascular conditions	411, 412, 413, 414.0, 414.01, 414.06, 414.2, 414.3, 414.4, 414.8, 414.9, V45.81, V45.82, 415, 416, 417, V12.55, 414.1, 429, 426, V45.0, V53.3, 427, 785.0, 785.1, 427.41, 427.42, 427.5, 394, 395, 396, 397, 424, 785.2 785.3, V42.2, V43.3, 398.91, 428, 410, 402, 404, 420, 421, 422, 423, 424, 425, 427, 393, 398, 429
Respiratory or lung disease	490, 491, 492, 494, 496, 493, 162, 209.21, 231.2, V10.11, V10.29, 518.83, 518.84, 518.89, 495, 500, 501, 502, 503, 504, 505, 506, 507.1, 507.8, 508
Neurodegenerative disorder	290, 294.1, 294.2, 331.0, 331.1, 331.89, 331.2, 331.7, 331.82, 797, 331.89, 331.9
Cerebrovascular disease	433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 346.6, 430, 431, 432, 433.01, 433.11, 433.21, 433.31 433.81, 433.91, 434, 436, 437.0, 437.1, 437.3, 437.4, 437.5, 437.6, 437.7, 437.8, 437.9, 435, 438