Differences in Heat-Related Mortality by Citizenship Status: United States, 2005–2014

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Abstract

Objectives—To determine whether non-US citizens have a higher mortality risk of heat-related deaths than do US citizens.

Methods—We used place of residence reported in mortality data from the National Vital Statistics System from 2005 to 2014 as a proxy for citizenship to examine differences in heat-related deaths between non-US and US citizens. Estimates from the US Census Bureau American Community Survey of self-reported citizenship status and place of birth provided the numbers for

the study population. We calculated the standardized mortality ratio and relative risk for heat-related deaths between non-US and US citizens nationally.

Results—Heat-related deaths accounted for 2.23% (n = 999) of deaths among non-US citizens and 0.02% (n = 4196) of deaths among US citizens. The age-adjusted standardized mortality ratio for non-US citizens compared with US citizens was 3.4 (95% confidence ratio [CI] = 3.2, 3.6). This risk was higher for Hispanic non-US citizens (risk ratio [RR] = 3.6; 95% CI = 3.2, 3.9) and non-US citizens aged 18 to 24 years (RR = 20.6; 95% CI = 16.5, 25.7).

Conclusions—We found an increased mortality risk among non-US citizens compared with US citizens for heat-related deaths, especially those younger and of Hispanic ethnicity.

A recent Centers for Disease Control and Prevention (CDC) Health Disparities and Inequality Report highlighted health disparities among racial, ethnic, geographic, and socioeconomic groups for several health outcomes and called for increased efforts to identify and measure these disparities so that barriers to health equity can be removed.[1] One study discussed in the CDC report documented a higher risk of work-related fatal injuries among Hispanic and foreign-born workers, with rates among Hispanics more than 1.5 times the US rate for work place–related fatalities resulting from exposure to harmful substances or environs, including exposure to extreme temperatures causing hyper- or hypothermia.[1]

In the United States, an average of 658 people died from exposure to excessive natural heat annually from 1999 to 2009,[2] and heat-related deaths are a leading cause of death from natural weather or environmental events.[3] These deaths are preventable, and numerous studies have described risk factors for increased mortality, including young or old age; minority race and ethnicity, particularly non-Hispanic Black[3]; low socioeconomic status; presence of comorbid conditions such as high blood pressure, heart disease, and mental illness; and lack of access to air conditioning.[3–5]

Differences in mortality among US immigrant populations are not routinely examined because of challenges in characterizing deaths among immigrants and difficulties in obtaining relevant population denominator data.[6] Previous studies, which have focused mainly on deaths among foreign-born individuals (defined as anyone who is not a US citizen at birth), found that foreign-born individuals have lower mortality rates than do US-born individuals[6,7]; in particular, foreign-born Hispanic young adults have lower mortality rates than do US-born White young adults.[8] Only a few studies looked at differences in health outcomes by citizenship status[9,10]; however, non-US citizens of working age are 52% less likely to have health insurance than are US citizens.[6] Current interventions in the United States to prevent heat-related deaths are based largely on risk factors identified following extreme heat events in urban areas. To determine whether a mortality differential exists for deaths associated with extreme heat among immigrants who may be at higher risk because of occupation, we compared heat-related deaths among non-US and US citizens from 2005 to 2014.

METHODS

In the United States, death certificates are completed for every death that occurs, and death certificate data are submitted for processing to the CDC's National Center for Health Statistics through the National Vital Statistics System (NVSS). Funeral directors, medical examiners, coroners, or attending physicians generally complete death certifi-cates,[11] and guidance for certification of death in the United States can be found in the *Medical Examiners' and Coroners' Handbook on Death Registration and Fetal Death Reporting.*[12] The medical examiner, coroner, or attending physician enters the causes of death and classifies them on the basis of the World Health Organization's 10th revision of *International Classification of Diseases* (*ICD-10*) codes.[13]

We used NVSS restricted mortality data (January 1, 2005, through December 31, 2014) to identify deaths from excessive heat exposure among non-US and US citizens, with place of residence as a proxy for citizenship. We defined heat-related deaths as those in which *ICD-10* code X30 (exposure to excessive natural heat) was reported as the underlying cause of death, and we did not consider deaths owing to *ICD-10* code W92 (exposure to excessive heat of human-made origin). The underlying cause of death is defined as the disease or injury that initiated the chain of events that led directly and inevitably to death and is selected on the basis of the sequence of diseases or conditions entered by the attending physician on the death certificate.[11] Because of the exploratory nature of this analysis, we chose to include only deaths clearly linked to excessive heat exposure to minimize potential misclassification that could not be accounted for because of limitations in death certificate data (CDC, personal communication, 2015).

Variables of interest included demographic characteristics (age, sex, race, and ethnicity), marital status and educational level of decedent, state where death occurred, month and year of death, place of injury, and place of residence as a proxy for citizenship. An informant familiar with the decedent provided race and ethnicity as reported on the death certificate, or, lacking an informant, race/ethnicity was provided on the basis of observation. Because of the limited number of non-White decedents, race was collapsed into 2 categories: White and other (Black or African American, American Indian/Alaska Native, Asian Pacific Islander, and other). Ethnicity was limited to Hispanic and non-Hispanic.[11] Options for marital status included married, divorced, never married, or widowed on the basis of the decedent's marital status at time of death.[12] State of occurrence of death is assigned on the basis of the address provided on the death certificate. Place of injury described where the excessive heat exposure occurred or where the decedent was found if the death was unattended. Locations included home, residential institution, school or other public administrative area, sports area, street or highway, trade area, industrial or construction area, farm, or other specified place.

Equation (1) gives the true risk ratio (RR) comparing deaths from excessive heat exposure between non-US and US citizens:

$$RR = \frac{D_{NC}/N_{NC}}{D_C/N_C} \quad (1)$$

where D_{NC} is the true number of heat-related deaths among non-US citizens, N_{NC} is the true number of non-US citizens, D_C is the true number of heat-related deaths among US citizens, and N_C is the true number of US citizens.

Because citizenship status of decedents (D_{NC} and D_C) was not available through NVSS, we used the resident status reported on the death certificate as a proxy (D_{NR} and D_R, where D_{NR} represents the number of heat-related deaths in non-US residents and D_R the number of heat-related deaths in US residents). NVSS resident status is from information on the decedent's residence listed on the death certificate. Resident city and state is defined as where the decedent's household is located, where the decedent actually resided, or where the decedent lived and slept most of the time. If decedents' death was classified in NVSS as occurring in 1 of the 50 states or the District of Columbia but whose place of residence was outside the United States, we considered them non-US citizens. We considered all other decedents US citizens.

There are statistical challenges with this proxy because if US citizens working overseas die while visiting the United States, their resident city and state is recorded as outside the United States. Conversely, if non-US citizens studying or working in the United States die in the United States, their residence is recorded as a US address. However, if we define x_1 as the number of non-US citizens who die in the United States and are classified by NVSS as a US resident and x_2 as the number of citizens who die in the United States and are classified by NVSS as non-US residents, the following relationships in Equation (2) hold:

$$D_{NC} = D_{NR} - x_1 + x_2 \quad (2)$$

$$D_C = D_R - x_1 + x_2$$

If $x_1 > x_2$ (i.e., if the number of non-US citizens who die in the United States and are classified by NVSS as a US resident exceeds the number of US citizens who die in the United States and are classified by NVSS as non-US residents), which seems likely, then using NVSS resident status in lieu of citizenship status would result in an underestimate of the true RR. We also conducted sensitivity analyses examining the effect of changes in the estimates of non-US and US citizens (Table A, available as a supplement to the online version of this article at http://www.ajph.org).

We conducted descriptive analyses and compared proportions of heat-related deaths among non-US and US citizens and assessed statistical significance ($P < .05$) using the Pearson χ^2 test in SAS version 9.3 (SAS Institute, Cary, NC). Self-reported citizenship in the US Census Bureau American Community Survey (ACS) 1-year estimates for the 9 years of our study provided the estimated number of non-US and US citizens. Further information on ACS methodology and determination of citizenship status can be found in the ACS code lists, definitions, and accuracy documentation (http://www.census.gov). We used numbers of native-born and foreign-born naturalized citizens to estimate the total population of US

citizens, and we used numbers of foreign-born non-US citizens to estimate the total population of non-US citizens.

We accessed ACS data through American Fact Finder (http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml) and extracted them from Table S0501: selected characteristics of the native- and foreign-born populations (for non-US and US citizens) for each year from 2005 to 2014. For sex-, age-, race-, and ethnicity-specific comparisons, ACS population estimates were presented as percentages of the total population and required back-calculation to arrive at integer values. We weighted differences between the generated and total population values by frequency for each stratum, and we added the weighted differences to the calculated values to arrive at the final population values used in this analysis. We generated an age-adjusted standardized mortality ratio and sex-, age-, race-, and ethnicity-stratified RRs and 95% confidence intervals (CIs) assuming a Poisson distribution for each stratum using SAS.

RESULTS

From January 1, 2005, through December 31, 2014, 25 002 475 deaths were reported to NVSS. Of these, 5195 (0.02%) deaths had *ICD-10* code X30 listed as the underlying cause of death and were classified as heat related. Heat-related deaths accounted for 999 (2.23%) deaths among non-US citizens compared with 4196 (0.02%) deaths among US citizens.

The majority of non-US citizen heat-related deaths were among adults aged 18 to 44 years (75.4%); by comparison, 20.7% of US citizen heat-related deaths were among adults aged 18 to 44 years (Table 1). Heat-related deaths of US citizens were more likely to occur among adults aged 45 years or older (69.4%), whereas 13.3% of non-US citizen heat-related deaths were among adults aged 45 years or older. Most heat-related deaths among non-US citizens occurred among Whites (97.7%) and Hispanics (86.7%) compared with heat-related deaths among US citizens (76.1% and 14.5%, respectively). Heat-related deaths among non-US citizens were more likely to occur on a farm (19.8%) than were heat-related deaths among US citizens (1.5%) and less likely to occur in a home (0.6% vs 38.5%). Three states (Arizona, California, and Texas) accounted for 945 (94.5%) non-US citizen deaths and 1564 (37.2%) US citizen deaths.

The age-adjusted standardized mortality ratio for non-US compared with US citizens was 3.4 (95% CI = 3.2, 3.6; Table 2). When we stratified by age, we found that non-US citizens aged 65 years or older had a lower risk of heat-related death than did US citizens of the same age (RR = 0.2; 95% CI = 0.1, 0.4), whereas non-US citizens aged 18 to 24 years had a markedly higher risk of heat-related death than did their US citizen counterparts (RR = 20.6; 95% CI = 16.5, 25.7; Table 2). When stratified by race and ethnicity, both White and Hispanic non-US citizens were at higher risk for heat-related death (RR = 6.2; 95% CI = 5.8, 6.7 and RR = 3.6; 95% CI = 3.2, 3.9, respectively; Table 2).

In additional analyses, we examined the effect of changes in non-US and US citizen populations by −50% to +50% (Table A) to assess the sensitivity of results to the effects of over- or underestimation of the US citizen population (N_C and N_{NC} in Equation 1) by use of

NVSS resident status as a proxy. When the non-US citizen population was increased by 50% and the US citizen population reduced by 50%, the risk of death for non-US citizens compared with US citizens was 1.03 (95% CI = 1.0, 1.11). For all other permutations, the risk of heat-related death for non-US citizens compared with US citizens ranged from 1.3 (95% CI = 1.2, 1.4) to 9.2 (95% CI = 8.7, 10.0) times higher.

DISCUSSION

We found disparities between non-US and US citizens who died from excessive heat exposure, with non-US citizen decedents being younger and predominantly White and Hispanic. Three states accounted for 95% of all heat-related non-US citizen deaths. It is unclear whether this mortality difference is because of differences in health, lifestyle, occupation, or cultural behaviors among this immigrant population or whether it reflects migration biases[14–16] or differences in access to health care. Non-US citizens have decreased access to health care,[6] which may play a role in our observed mortality difference.

Current Council of State and Territorial Epidemiologists reporting guidelines for climate and health indicators, including rate of heat deaths, specifically instruct state and local health departments to exclude all nonstate residents,[17] and previous regional and national reports have typically excluded non-US residents (as defined by NVSS).[18–20] To our knowledge, this is the first study that attempts to calculate heat-related mortality rates for both US and non-US citizens through a novel use of available Census data. On the basis of our findings, excluding non-US citizens could result in almost a 20% underestimation of the number of heat-related deaths occurring in the United States.

We found that non-US citizens aged 18 to 24 were 20 times more likely to die from excessive heat exposure than were US citizens. The high proportion of deaths among younger non-US citizens was unexpected because previous studies have generally found persons aged 65 years or older at higher risk for excessive heat exposure because of preexisting medical conditions, physiologic changes that limit the body's ability to cool itself, and psychiatric disorders.[3,4,19,20] We hypothesize that younger non-US citizens may engage in activities that put them at higher risk for excessive heat exposure, such as farming, illegal border crossing, or other outdoor activities.

For non-US citizens we found 19.8% of the decedent's place of excessive heat exposure or death recorded as "farm," 61.4% listed as "other specified place," and only 0.6% exposed at home.

However, we could not confirm a decedent's activity at the time of death on the basis of available NVSS data. Previous studies reported that crop workers are at higher risk for heat-related illness or death.[21–23] These workers tend to be younger, with 1 study of migrant farm workers finding almost 85% of survey participants aged between 18 and 44 years,[24] whereas another reported that 66% of hired crop workers were younger than 35 years.[25] Likewise, excessive heat exposure has also been reported as a leading cause of death among migrants illegally attempting to cross into the United States, with most decedents between the ages of 20 and 29 years.[26]

We found that more than 85% of non-US citizens who died of excessive heat exposure were of Hispanic ethnicity compared with less than 15% of US citizens. According to national guidelines, funeral directors, coroners, or medical examiners should complete demographic information on the death certificates on the basis of information family members or friends of the decedent provide.[12] However, some information, such as race and ethnicity, may be obtained indirectly, particularly when a family member or friend is not available.[14] Although this practice could result in misclassifications, previous studies have shown that death certificate data are likely to underestimate Hispanic ethnicity by only about 5%, with Hispanic ethnicity more reliable for foreign-born than US-born decedents.[14] Therefore, whereas some decedents in this study may have been misclassified, this did not account for all the difference in ethnicity observed between decedents by residency status. In the United States from 2003 to 2006, 20 of 28 (71%) deceased crop workers were from Mexico or Central or South America,[22] and overall 95% of foreign-born hired crop workers reported immigrating from Mexico.[25] Hispanics also accounted for a large proportion of deaths related to illegal border crossings, with 99% of decedents originating in Mexico.[26]

Among foreign transients in the US– Mexico border region, deaths from environmental heat, cold, exposure, and dehydration skyrocketed from 1995 to 2000 as a result of changing immigration patterns.[27] A 2003 study attributed almost 73% of deaths among migrants attempting unauthorized border crossings to exposure or probable exposure to excessive heat,[18] and 75% of deaths along the US–Mexico border occur in the Arizona desert.[28] In a 2012 report, the Arizona Department of Health Services found that 1535 heat-related deaths took place in Arizona from 2000 to 2012, and 47.9% of these occurred in migrants from Mexico, Central America, or South America. Among migrants from these countries, 71% of heat-related deaths occurred in adults aged 20 to 44 years.[29]

In a 2010 report, the Arizona Department of Health Services found that 45% of 1485 heat-related deaths occurred among illegal immigrants crossing the US–Mexico border. Four counties along the southern Arizona border accounted for 90% of heat-related deaths among illegal immigrants, and most deaths in this population occurred from 2000 to 2007, possibly as a result of increased numbers of attempted crossings in Arizona following stricter border security measures in California and Texas.[30] In Arizona, only 82 heat-related deaths in the 2012 report and 95 heat-related deaths in the 2010 report were attributed to visitors from other US states, Canada, or Europe.[29,30] It is interesting to note that, in our study, the 3 states that accounted for almost 95% of non-US citizen deaths are located along the US–Mexico border (Arizona, California, and Texas). Southwestern states account for approximately 40% of farmworkers in the United States.[31]

Limitations

This study has several limitations. Detailed NVSS data describing the circumstances of death may vary on the basis of what information is available from the investigation process, resources, and the person completing the death certificate. Therefore, these data might not provide the necessary information to explain the situation or series of events leading to death from excessive heat exposure among non-US citizens. Thus, we were not able to identify contributing risk factors, such as lack of air conditioning, limited access to fluids, or

physical exertion, that might have contributed to death. As an example, although we reported that almost 20% of non-US citizen excessive heat exposures or deaths occurred on a farm, we were unable to determine whether these individuals were engaged in paid labor at the time of exposure.

The use of NVSS resident data as a proxy for deaths by citizenship status may have led to an underestimation in the risk of heat-related deaths among non-US citizens; however, we were unable to determine the magnitude of the underestimation. Additionally, although ACS provides population estimates for foreign-born non-US citizens, these may underestimate the number of unauthorized immigrants by 1.1 million.[32] Likewise, whereas ACS enumerates individuals living in group quarters, including emergency and transitional shelters, not all homeless individuals may be captured. Similarly, NVSS may fail to correctly capture residency status of unidentified decedents, although efforts are made by US Customs and Border Protection and medical examiners and coroners to identify all individuals who die in the process of border crossing.[33]

Because of heterogeneity in populations, NVSS resident data as a proxy for citizenship status should not be used to conduct comparisons between states or at less than a national level. This prohibited us from examining whether larger non-US citizen populations in warmer states (e.g., Arizona, California, and Texas) might explain some increased risk of heat-related deaths among non-US citizens.

Finally, whereas death certificate training and guidance are available to ensure consistency among certifiers, the cause of death is ultimately documented by a single individual, which could lead to variability in the classification of deaths as heat related or non–heat related. To minimize this potential misclassification, we evaluated only deaths with heat exposure as an underlying cause. Certifiers often rely on information provided by friends or family members of the decedent to establish demographics such as race or ethnicity, so misclassification for these, particularly when someone close to the decedent cannot be identified, may also occur.

Public Health Implications

Current public health interventions to reduce illness and death from exposure to extreme heat include public outreach to urban populations to increase awareness of heat exposure symptoms and provide advice for staying cool, particularly for vulnerable or socially isolated individuals; increased access to air conditioning through centralized cooling stations and extended hours of operation for public locations with air conditioning; and suspending utility shutoffs during periods of extreme temperatures.[34,35]

Our findings indicate that these interventions may not help prevent heat-related deaths among non-US citizens. Additional studies describing key characteristics of non-US citizen decedents can help determine whether risk factors for non-US citizen heat-related deaths are similar to or different from those previously identified for US citizens, such as occupation, length of time in the United States before death, language spoken, and circumstances of death. Although some states, such as Arizona, are already collecting this type of information, standardized data collection across all states may provide reliable information

for prevention efforts such as the Border Safety Initiative and for the design and implementation of new public health interventions targeting non-US citizens.

Clear disparities for heat-related deaths exist for non-US citizens. Standard public health case definitions that exclude non-US citizens underestimate the burden of heat-related deaths and may have contributed to the previous lack of reporting of health disparities among individuals who die of nonoccupational excessive heat exposure. Future studies characterizing non-US citizen decedents may more clearly identify risk factors leading to increased risk of excessive heat exposure, such as illegal border crossing or migrant or seasonal farmwork. When designing preventive strategies for heat-related mortality, language differences, culture, and economic status are factors to consider. States with high numbers of non-US citizens could consider routinely conducting additional analyses to track non-US citizen deaths and implementing specific interventions to prevent heat exposure in this population in addition to existing activities targeting previously identified high-risk groups.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1

Characteristics of US Citizens and non-US Citizens Who Died From Heat: United States, 2005–2014

Characteristic	US Citizens (n = 4196), No. (%)	Non-US Citizens (n = 999), No. (%)	P
Sex			< .001
Male	2931 (69.9)	799 (80.0)	
Female	1265 (30.1)	200 (20.0)	
Age, y			< .001
< 5	310 (7.4)	2 (0.2)	
5–17	70 (1.7)	41 (4.1)	
18–24	120 (2.9)	226 (22.6)	
25–44	748 (17.8)	527 (52.8)	
45–64	1439 (34.3)	122 (12.2)	
65	1471 (35.1)	11 (1.1)	
Unknown	38 (0.9)	70 (7.0)	
Marital status			< .001
Divorced	832 (19.8)	19 (1.9)	
Married	936 (22.3)	377 (37.7)	
Single	1550 (36.9)	478 (47.8)	
Widowed	646 (15.4)	10 (1.0)	
Unknown	232 (5.5)	115 (11.5)	
Race			< .001
White	3195 (76.1)	976 (97.7)	
Other	1001 (23.9)	23 (2.3)	
Ethnicity			< .001
Hispanic	607 (14.5)	866 (86.7)	
Non-Hispanic	3518 (83.8)	55 (5.5)	
Unknown	71 (1.7)	78 (7.8)	
Education			< .001
No high school	856 (20.4)	500 (50.1)	
Some high school	1951 (46.5)	300 (30.0)	
Some college	997 (23.8)	39 (3.9)	
Unknown	392 (9.3)	160 (16.0)	
Place of excessive heat exposure			< .001
Farm	62 (1.5)	198 (19.8)	
Home	1617 (38.5)	6 (0.6)	
Industrial or construction area	67 (1.6)	5 (0.5)	
Street or highway	318 (7.6)	39 (3.9)	
Trade area	73 (1.7)	5 (0.5)	
Other[a]	932 (22.2)	613 (61.4)	

Characteristic	US Citizens (n = 4196), No. (%)	Non-US Citizens (n = 999), No. (%)	P
Unspecified	1127 (26.9)	133 (13.3)	

[a] Other places of excessive heat exposure are the following: other specified area (801 US citizen deaths, 609 non-US citizen deaths), residential institution (56 US citizen deaths), school or public area (56 US citizen deaths, 3 non-US citizen deaths), and sports area (19 US citizen deaths, 1 non-US citizen death).

TABLE 2

Risk Ratio for Heat-Related Deaths Among Non-US Citizens Compared With US Citizens, Stratified by Sex, Age, Race, and Ethnicity and Age-Adjusted Standardized Mortality Ratio (SMR): United States, 2005–2014

Characteristic	RR (95% CI)
Sex	
Male	3.3 (3.1, 3.6)
Female	2.2 (1.9, 2.6)
Age, y	
< 5	0.6 (0.2, 2.4)
5–17	15.6 (10.6, 22.9)
18–24	20.6 (16.5, 25.7)
25–44	4.6 (4.2, 5.2)
45–64	1.3 (1.1, 1.6)
65	0.2 (0.1, 0.4)
Race	
White	6.2 (5.8, 6.7)
Other	0.1 (0.1, 0.2)
Ethnicity	
Hispanic	3.6 (3.2, 3.9)
Non-Hispanic	0.9 (0.7, 1.1)
Age-adjusted SMR	3.4 (3.2, 3.6)

Note. CI = confidence interval; RR = risk ratio. We excluded decedents with data missing for age (n = 108) or ethnicity (n = 149). We set US citizens as the reference group.