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Deaths Attributed to Heat, Cold, and Other Weather Events in the United States, 2006–2010

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Abstract

Objectives—This report examines heat-related mortality, cold-related mortality, and other weather-related mortality during 2006–2010 among subgroups of U.S. residents.

Methods—Weather-related death rates for demographic and area-based subgroups were computed using death certificate information. Adjusted odds ratios for weather-related deaths among subgroups were estimated using logistic regression.

Results and Conclusions—During 2006–2010, about 2,000 U.S. residents died each year from weather-related causes of death. About 31% of these deaths were attributed to exposure to excessive natural heat, heat stroke, sun stroke, or all; 63% were attributed to exposure to excessive natural cold, hypothermia, or both; and the remaining 6% were attributed to floods, storms, or lightning. Weather-related death rates varied by age, race and ethnicity, sex, and characteristics of decedent's county of residence (median income, region, and urbanization level). Adjustment for region and urbanization decreased the risk of heat-related mortality among Hispanic persons and increased the risk of cold-related mortality among non-Hispanic black persons, compared with non-Hispanic white persons. Adjustment also increased the risk of heat-related mortality and attenuated the risk of cold-related mortality for counties in the lower three income quartiles.

The differentials in weather-related mortality observed among demographic subgroups during 2006–2010 in the United States were consistent with those observed in previous national studies. This study demonstrated that a better understanding of subpopulations at risk from weather-related mortality can be obtained by considering area-based variables (county median household income, region, and urbanization level) when examining weather-related mortality patterns.

Keywords: weather-related mortality • vulnerable subpopulations • mortality • National Vital Statistics System

Introduction

Extreme weather (heat, cold, storms, floods, and lightning) has long been associated with excess morbidity and mortality. Studies of weather-related morbidity and mortality have sought both to quantify the magnitude of the problem and to identify vulnerable subpopulations so that appropriate public health interventions can be designed and implemented. The frequency and intensity of all types of extreme weather events (heat waves, cold snaps, floods, storms, and lightning) is expected to increase in the future as a result of changing weather patterns (1).

Exposure to extreme natural heat poses a public health problem because it may result in heat-related illness (e.g., heat cramps, heat exhaustion, heat syncope, and heat stroke) and heat-related death. Exposure to extreme natural heat also may result in death because it exacerbates preexisting chronic conditions (e.g., cardiovascular, cerebral, and respiratory diseases), and because patients receiving psychotropic drug treatment for mental disorders and those taking medications that affect the body's heat regulatory system or have anticholinergic effects are more susceptible to heat effects (2–14).

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Numerous studies have identified subpopulations at increased risk of heat-related morbidity and mortality: older adults, young children (0–4 years), males, and black persons (2,3,8–13, 15–20). Moreover, alcoholics, narcotics users, persons confined to bed or unable to care for themselves, socially isolated persons, those living on the top floor of multistory buildings, those without access to air conditioning, and persons who work or exercise outdoors are also at increased risk (2,3,8–13,16–21). The combined effects of a warming climate, the aging U.S. population, and the increasing number of people living in urban areas (where the urban heat island effect exacerbates the effects of high ambient temperatures) may result in an increasing number of people at risk of heat-related death (12,22).

Exposure to extreme natural cold also is associated with morbidity and mortality. It can lead to hypothermia, which may result in death. Moreover, it may result in death because it can exacerbate preexisting chronic conditions (including cardiovascular and respiratory diseases), and because persons with conditions that impair thermoregulatory function and those taking various medications are more susceptible to cold effects (2,8–11,13,15,16,23–28). Subpopulations at risk for cold-related mortality are similar to those at risk for heat-related mortality: older adults, infants, males, black persons, and persons with preexisting chronic medical conditions (2,11,15,16,23–27,29). Alcoholics, persons taking recreational drugs (especially alcohol), homeless persons, those with inadequate winter clothing or home heating, those who go on wilderness excursions, and those who participate in winter sports also are at increased risk of cold-related mortality (23,24,26). Persons who live in places with rapid temperature changes, large shifts in nighttime temperatures, or are at high elevations also are at increased risk (27). While average winter temperatures across the United States have risen since the late 1970s, many areas continue to experience periods of extremely low temperatures.

Other weather events, including floods; cataclysmic storms (e.g., hurricanes, tornados, blizzards, and torrential rains); and lightning account for additional weather-related deaths (15,30–36). Floods, storms, and lightning may lead directly to death (e.g., drowning during a flood) or may result in death because they exacerbate preexisting medical conditions such as cardiovascular disease (15,25,30–42). Vulnerable subpopulations include males, white persons, older adults, and youths aged 5–14 (15,30–36). Substance abuse, alcohol use, and unnecessary risk taking contribute to flood, storm, and lightning deaths (30–36).

Two broad approaches have been used to study weather-related mortality. The first approach models associations between temperatures and mortality (often all-cause mortality) to assess whether there is evidence of excess mortality during periods of extreme hot or cold weather and to identify which subpopulations are at increased risk. The premise of these studies is that increases in mortality observed for warmer or colder days are weather-related. Such deaths may or may not be attributed to heat-related or cold-related causes of death on the death certificate. Some studies of this type compare the number of deaths that occurred in a particular location during a specific heat wave or cold snap with the number of deaths that occurred during a period without extreme weather to determine if an excessive number of deaths occurred during the weather event and, if so, to whom (3,19,43).

For example, Semenza et al. calculated the number of excess deaths that occurred during the July 1995 Chicago heat wave and reported that people with preexisting health conditions, people who lacked social support, and people who did not have access to air conditioning were at increased risk of death during the heat wave (3). Other studies of this type use time series of daily temperatures and death counts (often over long periods of time and for multiple locations) to model the relationship between the high or low temperature on a given day, and all-cause mortality on that day or over a few days lagged (8–11,44). For example, Anderson and Bell analyzed daily high temperatures and mortality in 43 U.S. cities during 1987–2005 and found that all-cause mortality increased 3.7% during heat waves, and that an increase of 1 degree Fahrenheit was associated with a statistically significant increase in mortality (44).

The second approach used to study weather-related mortality examines deaths attributed to weather-related causes of death (listed as underlying or contributing causes or both on the death certificate) (15,21,23,25,27,29,31,37,38, 42,45). Studies of this type do not use any weather data. They examine the number of deaths attributed to weather-related causes of death and the characteristics of the decedents during specific time periods or over time. This approach provides counts of deaths directly attributed to weather, rather than estimates of ''excess'' deaths that occurred during extreme weather events.

The burden of heat-related and cold-related illness and death is generally recognized to be underestimated when the estimates are derived from death certificate data. Heat-related and cold-related causes of death may not be listed on the death certificate because of difficulties in making such diagnoses (13,25,26,46). Determination that a death is heat-related or cold-related requires knowledge of the decedent's core body temperature at the time of death or knowledge that the decedent was exposed to hot or cold ambient temperatures. Unless medical personnel are present at the death, core body temperature at time of death generally is not known. The person completing the death certificate may be unaware of extreme temperature exposures prior to death, particularly if the death occurs at home (e.g., if an elderly person dies at home and the home was underheated, this contributing cause may not be noted). Additionally, heat and cold may not be listed on the death certificate as contributing causes of death for deaths resulting from exacerbation of a preexisting medical condition (7,13,15,46,47). Lack of consistent diagnostic criteria also contributes to underestimation of heat-related and cold-related mortality (13,30,46–48).

Flood, storm, and lightning deaths also are known to be underestimated (35,36,49,50). Although weather-related mortality derived from death certificates has limitations, the vital statistics system is the only data source with data for the entire United States, for extensive time periods, and for all types of weather-related mortality. Studies using vital statistics data can provide information about the geography of weather-related mortality (national, regional, subregional, nonmetropolitan, and metropolitan) and enable comparisons across geographic units. Studies that use vital statistics data also support comparisons between the different types of weather-related mortality with regard to mortality levels, distribution, and vulnerable subpopulations. Because of these features, vital statistics data are used by organizations such as the World Health Organization, the National Institute of Environmental Health Sciences, the National Climate Assessment Development Advisory Committee (which brings together researchers from 13 different U.S. federal agencies), and the Centers for Disease Control and Prevention's Climate and Health Program to monitor weather-related mortality (48,51–53).

This study used the second analytic approach to examine deaths of U.S. residents that occurred during 2006–2010 and were attributed to weather. Information from death certificates was used to identify deaths attributed to excessive natural heat, excessive natural cold, floods, cataclysmic storms, or lightning, and to examine these deaths by age group, sex, race and Hispanic origin, region, urbanization level, and county median household income.

Methods

This study used 2006–2010 microdata death files produced by the National Center for Health Statistics (NCHS) (54). These files are derived from death records in the National Vital Statistics System. Death records in the National Vital Statistics System are derived from death certificates collected by the states and tabulated by NCHS. Each death certificate may contain up to 20 cause-of-death conditions (55–59). The underlying cause of death, which is defined by the World Health Organization as ''the disease or injury which initiated the train of events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury,'' is selected from among the conditions entered in the cause-of-death section of the death certificate (55,60). For 2006–2010, cause of death was coded in accordance with the 10th revision of the *International Classification of Diseases* (ICD–10) (60).

This study includes deaths attributed to weather-related causes (i.e., heat, cold, floods, storms, and lightning) that occurred to U.S. residents in the 50 states and the District of Columbia during 2006–2010. Deaths with an underlying or contributing cause attributed to a weather-related cause of death were included. Heat-related deaths are those with any mention on the death certificate of ICD–10 codes X30 (exposure to excessive natural heat), T67 (heatstroke or sunstroke), or both. Cold-related deaths are those with any mention on the death certificate of ICD–10 codes X31 (exposure to excessive natural cold), T68 (hypothermia), or both. Flood-storm-lightning-related deaths are those with any mention of ICD–10 codes X38 (victim of flood), X37 (victim of cataclysmic storm), or X33 (victim of lightning). Any of these ICD codes may be listed as a contributing cause, but only X30, X31, X33, X37, and X38 may be listed as the underlying cause of death (60).

Deaths due to weather (extreme natural heat, extreme natural cold, floods, storms, and lightning) may be identified by using both the underlying and contributing causes of death (23,29). Examination of death records with any mention of a weather-related cause of death (underlying or contributing or both) during 2006–2010 shows that using only the underlying cause of death to identify weather-related deaths results in omission of a substantial number of heat-related and cold-related deaths (Table 1). Among deaths attributed to natural heat, X30 (exposure to excessive natural heat) was listed as the underlying cause of death for only 61% of them. Inclusion of deaths for which X30 was mentioned as a contributing cause but not as the underlying cause, and inclusion of deaths for which T67 (heatstroke and sunstroke) but not X30 was mentioned, resulted in a 64% increase in the number of heat-related deaths in the analysis. When X30 was not the underlying cause of a heat-related death, heart disease or unintentional injuries was most frequently the underlying cause (53% and 20% of heat-related deaths).

Among deaths attributed to natural cold during 2006–2010, X31 (exposure to excessive natural cold) was listed as the underlying cause of death for 48% of them. Inclusion of deaths for which X31 was mentioned as a contributing cause but not as the underlying cause, and inclusion of deaths for which T68 (hypothermia) but not X31 was mentioned, more than doubled the number of cold-related deaths. When X31 was not the underlying cause of a cold-related death, unintentional injuries or heart disease was most frequently the underlying cause (54% and 17% of cold-related deaths). Nearly all (98%) flood-storm-lightning-related deaths can be identified using underlying cause of death only. Nearly all weather-related deaths were attributed to only one type of weather event; five deaths were attributed to both cold and storms.

Information on each decedent's age, sex, race and Hispanic origin, and the county where the death occurred was obtained from the death certificate. A recent evaluation study of the validity of race and Hispanic origin reporting on U.S. death certificates concluded that reporting is excellent for non-Hispanic white and black populations and reasonably good (about 5% underreporting) for the Hispanic population (61). Further, the study found virtually no misclassification or variability by region or urban-rural status for the white and black populations and little variability in misclassification by region or urban-rural status for the Hispanic population. Despite this, death rates for Hispanic persons should be interpreted with caution because of underreporting (55).

The county where the death occurred was used to assign census region, county median household income, and county urbanization level. The urbanization level of counties was based on the 2006 NCHS Urban-Rural Classification Scheme for Counties (62). The 2006 NCHS scheme categorizes all U.S. counties and county equivalent entities into six levels: four for metropolitan counties (large central metro, large fringe metro, medium metro, and small metro) and two for nonmetropolitan counties (micropolitan and noncore). The assignment of counties as metropolitan or nonmetropolitan is based on the Office of Management and Budget's (OMB) metropolitan-nonmetropolitan classification. The large central metro category contains counties in metropolitan statistical areas (MSAs) of 1 million or more population that have been identified by NCHS classification rules as central because they contain all or part of a principal city of the area. The large fringe metro category contains the remaining counties (similar to suburbs) in MSAs of 1 million or more. Counties in MSAs of 250,000–999,999 population are assigned to the medium metro category, and counties in MSAs with populations under 250,000 are assigned to the small metro category. Nonmetropolitan counties that are designated by OMB as belonging to a micropolitan statistical area are assigned to the micropolitan category of the NCHS scheme. The remaining nonmetropolitan counties are assigned to the noncore category. The large central metro category is the most ''urban'' category, and the noncore category is the most ''rural'' category.

The U.S. Census Bureau's Small Area Income and Poverty Estimate program of 2008 county median household income was used to categorize counties into income quartiles (63). The U.S. population is not evenly distributed across the four income quartiles: 59% reside in counties in the highest income quartile, 24% in the second-highest quartile, 11% in the third quartile, and 6% in the lowest quartile.

Bridged-race estimates of the resident population of counties produced by the Census Bureau in collaboration with NCHS were used for death rate calculations (64,65). For 2006–2009, the estimates are July 1 bridged-race revised intercensal estimates; for 2010, they are April 1 bridged-race census counts.

Death counts and rates are presented for heat-related; cold-related; and combined flood, storm, and lightning deaths. Statistics are only presented for combined flood, storm, and lightning deaths because the number of deaths for these causes was small. Death counts and death rates presented for regions, urbanization levels, and median income quartiles were calculated by place of occurrence because, for these variables, place of occurrence was considered a better marker than place of residence for effects of weather events and availability of local response resources. Rates by place of residence also were computed as a sensitivity analysis; results were similar (not shown).

Age-specific death rates were computed by dividing the total number of deaths in each age group by the population estimate and multiplying by 1,000,000. Death rates by sex, race and Hispanic origin, region, urbanization level, and median household income were age-adjusted to the 2000 U.S. standard population using the direct method (66). The study used age-adjusted rates because the age-specific death rates varied considerably, and the age distribution varied by race and Hispanic origin, region, urbanization level, and income. Persons with age not stated on the death certificate (N = 37) were excluded from the analysis. Persons with Hispanic origin not stated on the death certificate (N = 74) were excluded from the race and Hispanic origin rate calculations and logistic models. Non-Hispanic persons of Asian, Hawaiian or Pacific Islander, or American Indian or Alaska Native race also were excluded from the race and Hispanic origin rate calculations due to small numbers.

To explore associations between geography and urbanization level and weather-related deaths, the study calculated age-adjusted death rates by urbanization level within each of the four regions. Logistic models were fit to examine the impact of controlling for region and urbanization level on weather-related death rates for various subgroups. One set of models included age (three categories), sex, race and Hispanic origin, and county median income quartiles; the second set also included region and urbanization level.

Mortality data, even based on complete counts, may be affected by random variation—that is, the number of deaths that actually occurred may be considered one of a large series of possible results that could have arisen under the same circumstances (67). The determination of statistical inference for death rates is based on the two-tailed z test. The Bonferonni inequality was used to establish the critical value for statistically significant differences (overall level of significance of 0.05) based on the number of possible comparisons within a particular variable (or combination of variables) of interest. Confidence intervals for odds ratios from the logistic regression models were not adjusted for the number of categories. Terms relating to differences such as ''greater than'' or ''less than'' indicate that the difference is statistically significant. Lack of comment regarding the difference does not mean that the difference was tested and found to be not significant.

Results

During 2006–2010, 10,649 deaths of U.S. residents were attributed to weather-related causes of death (Table 2). Exposure to excessive natural heat, heat stroke, sun stroke, or all were cited as either the underlying cause or a contributing cause of death for 3,332 (31%) of these deaths, and exposure to excessive natural cold, hypothermia, or both was cited for 6,660 (63%) of deaths. The remaining weather-related deaths were attributed to floods, storms, or lightning.

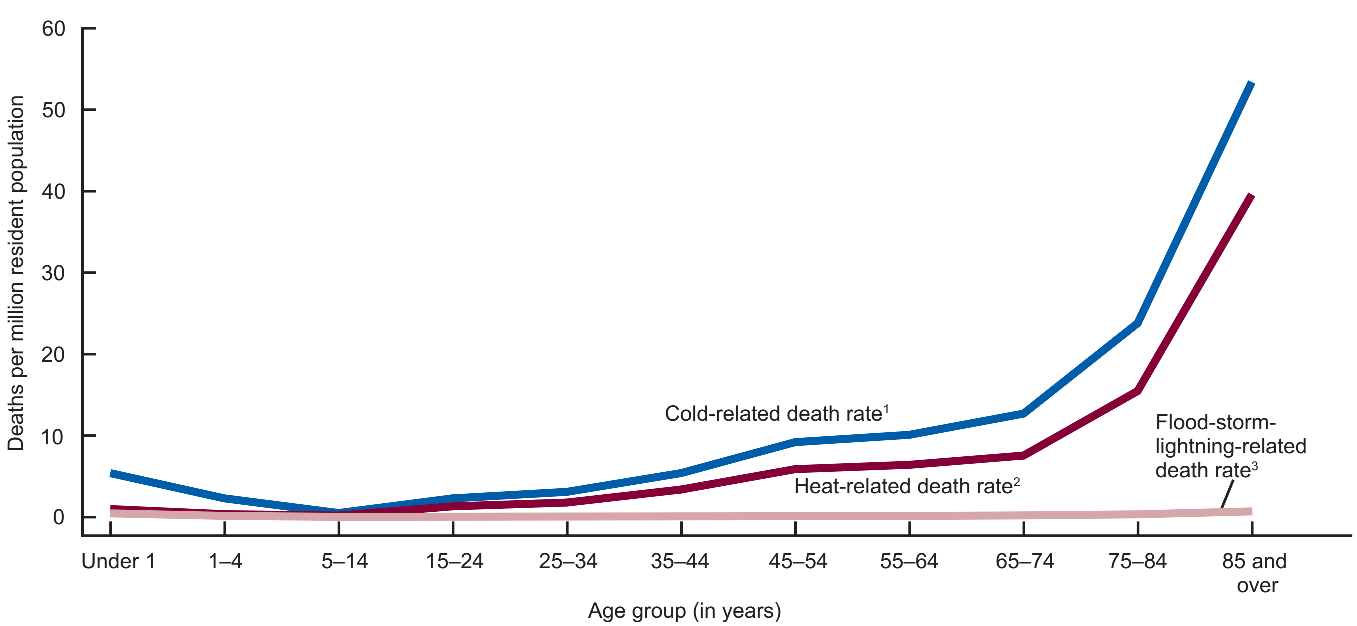
Heat-related, cold-related, and other weather-related death rates varied by age (Figure 1 and Table 2). The pattern across age groups was similar for heat-related and cold-related mortality: progressive moderate increases in the death rates between ages 15 and 74, a substantial increase in the death rate for persons aged 75–84, and an even larger increase in the rate for persons aged 85 and over. The heat-related death rate for infants was higher than the cold-related death rate (4.2 compared with 1.0 deaths per million), but among persons aged 5 years and over, cold-related death rates were consistently higher than heat-related death rates, and the differentials in the rates across the age groups were larger. The heat-related death rate was lowest for children aged 5–14 years (0.1 deaths per million) and increased from 0.5 deaths per million among persons aged 15–24 to 4.5 deaths per million among persons aged 65–74. The rates for persons aged 75–84 (7.5 deaths per million) and persons aged 85 and over (12.8 deaths per million) were substantially higher than those for younger persons. The heat-related death rate for infants (4.2 deaths) was higher than the rates for persons aged 1–44 and as high as the rates for persons aged 45–64.

The cold-related death rate for infants was 1.0 deaths per million, which was higher than the rate for children aged 5–14 but lower than the rates for persons aged 25 and over. Cold-related death rates were lowest for children aged 5–14 (0.2 deaths per million) and increased progressively with age, as was the case for heat-related mortality, with rates increasing from 1.3 to 7.8 deaths per million among persons aged 15–74. The cold-related death rates for persons aged 75 and over were substantially higher than the rates for younger persons: 15.5 deaths per million among persons aged 75–84 and 39.6 deaths per million among persons aged 85 and over.

The rate of deaths attributed to floods, storms, and lightning was low in all age groups (ranging from 0.2 deaths per million for children aged 14 years and under to 1.0 for persons aged 85 and over). Generally, differences among the age groups were not statistically significant for flood-storm-lightning-related mortality.

During 2006–2010, about 68% of the weather-related deaths were among males (Table 3). The age-adjusted heat-related and cold-related death rates for males were more than 2.5 times as high as those for females (3.1 compared with 1.2 deaths per million for heat-related mortality and 6.3 compared with 2.4 for cold-related mortality). Males were twice as likely as females to die due to floods, storms, or lightning (0.6 compared with 0.3 deaths per million).

Non-Hispanic black persons had higher rates of heat-related and cold-related mortality than other race and ethnicity groups during 2006–2010 (Table 3). For heat-related mortality, the rate for non-Hispanic black persons was about 2.5 times that for non-Hispanic white persons and about 2 times as high as that for Hispanic persons. The age-adjusted cold-related death rate for non-Hispanic black persons was 5.8 deaths per million compared with 4.1



[1]Deaths attributed to exposure to excessive natural cold (X31) (underlying or contributing cause of death or both), to hypothermia (T68) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.
[2]Deaths attributed to exposure to excessive natural heat (X30) (underlying or contributing cause of death or both), to heat stroke or sunstroke (T67) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.
[3]Deaths attributed to floods (X38), cataclysmic storms (X37), or lightning (X33) (underlying or contributing cause of death or both), according to the *International Classification of Diseases, 10th Revision*.
SOURCE: CDC/NCHS, National Vital Statistics System, 2006–2010.

Figure 1. Crude death rates for weather-related mortality, by age: United States, 2006–2010

for non-Hispanic white persons and 2.1 for Hispanic persons. Non-Hispanic white persons were more likely than non-Hispanic black or Hispanic persons to die due to floods, storms, or lightning.

Most of the heat-related deaths occurred in the South and West (43% and 33%, respectively) (Table 3). The West had the highest age-adjusted heat-related death rate (3.2 deaths per million); the Northeast and Midwest had similarly low age-adjusted heat-related death rates (1.1 and 1.3 deaths per million, respectively). The South, Midwest, and West each had about 1,800 cold-related deaths during 2006–2010 (the Northeast had fewer, with 1,200 such deaths). Although the South, Midwest, and West had a similar cold-related mortality burden, the South had a lower age-adjusted cold-related death rate (3.2 deaths per million compared with 5.2 and 5.0 for the Midwest and West). The Northeast and West had similarly low rates of death due to floods, storms, or lightning; the South had the highest rate (0.7 deaths per million).

Age-adjusted weather-related death rates varied by urbanization level; the urban-rural patterns varied somewhat by region (Tables 3 and 4 and Figure 2). For the United States as a whole and in each region, heat-related death rates for the most rural counties were as high as those for large central metro counties (for the United States, 2.6 deaths per million for the most rural counties and 3.1 for large central metro counties). Generally, large fringe metro, medium metro, small metro, and micropolitan counties had similar heat-related death rates that were lower than the rates for large central metro counties (for the United States, 1.8 to 2.2 deaths per million). In the South, the rate for large fringe metro counties was lower than those for other counties, and the rates for small metro- and micropolitan counties were as high as the rate for large central metro counties. For the United States as a whole, age-adjusted cold-related death rates were lowest in counties of the largest metropolitan areas (3.2 deaths per million in large central metro counties and 2.8 in large fringe metro counties), and highest in the most rural (noncore) counties (9.8 deaths per million). In the Northeast, Midwest, and South, cold-related death rates generally were lowest in the large fringe metro counties; similarly higher in large central metro, medium metro, small metro, and micropolitan counties; and highest in noncore counties. For example, in the Midwest, the cold-related death rate in large fringe counties was 3.3 deaths per million, the rate in the other urban counties and the micropolitan counties ranged between 5.1 and 5.4, and the rate in noncore counties was 9.5.

The urban-rural pattern in the West differed from that in the other regions. In the West, cold-related mortality increased steadily as counties became less urban, and the differential between the rates for the most rural and other counties was considerable (30.9 compared with 1.8 to 12.9 deaths per million). The rate of deaths attributed to floods, storms, or lightning was lowest in large central metro counties (0.2 deaths per million) and increased as counties became more rural. The rate in noncore counties was higher than the rate in other counties (1.6 deaths per million compared with 0.2 to 0.9 deaths per million).

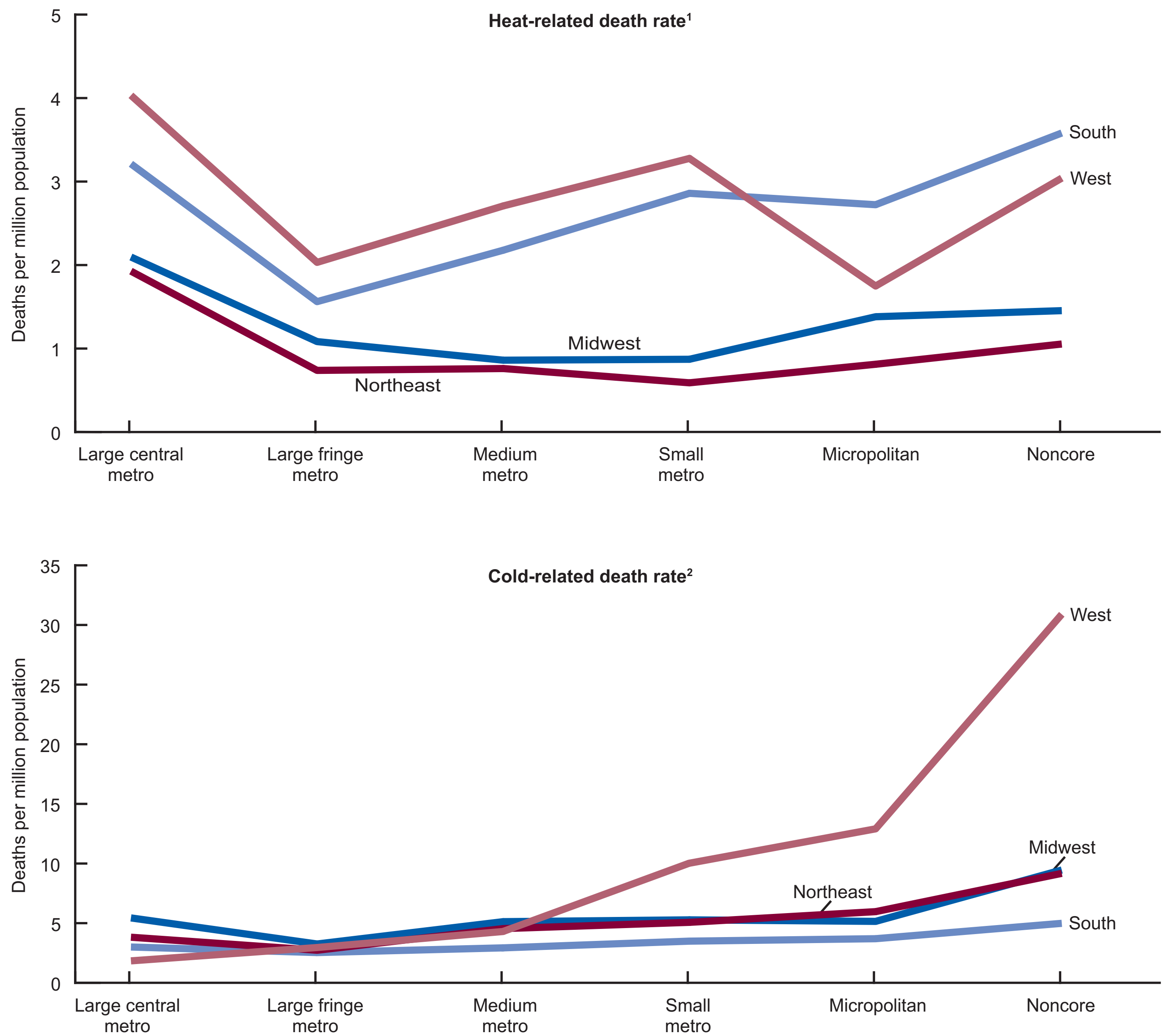
Counties in the highest quartile of median household income had the lowest rates of death due to any of the weather-related causes (Table 3). The age-adjusted heat-related and cold-related death rates for counties in the lowest median household income quartile were about 2 times as high as those for counties in the highest quartile. However, the highest frequency of weather-related deaths occurred in the highest income counties (2,957 cold-related and 1,658 heat-related deaths).

Table 5 shows the adjusted risk of weather-related mortality derived from two sets of logistic models. The first set of models includes age, sex, race and Hispanic origin, and county median income, and the second set includes these variables and region and urbanization level. The odds ratios (OR) from the first set of models were consistent with the univariate relationships observed among the age-adjusted death rates in Table 3. Adjustment for region and urbanization level changed some of the relationships observed among the demographic subgroups. For heat-related mortality, adjustment for region and urbanization level changed the ORs for Hispanic persons and for counties in the lower three quartiles of median household income. Specifically, after adjustment for region and urbanization level, Hispanic persons were at less risk of a heat-related death than non-Hispanic white persons, rather than at greater risk as they were before adjustment (OR = 0.89 after adjustment for region and urbanization level compared with 1.26 before adjustment).

Adjustment for region and urbanization level increased the risk of heat-related mortality for counties in the lower three income quartiles compared with counties in the highest income quartile. In contrast to the impact of adjustment on heat-related mortality, adjustment for region and urbanization level slightly increased the risk of cold-related mortality for non-Hispanic black persons compared with non-Hispanic white persons (from 1.35 to 1.73).

Also, in contrast to the impact of adjustment on heat-related mortality, adjustment for region and urbanization level attenuated the risk of cold-related mortality for counties in the lower three median income quartiles compared with counties in the highest median income quartile.

As for cold-related mortality, adjustment for region and urbanization level attenuated the risk of flood, storm, or lightning deaths for counties in the lowest two income quartiles (the OR for counties in the lowest income quartile decreased from 7.38 to 3.16 after adjustment). Modeling county median income as an ordinal variable rather than as a set of three dichotomous variables indicated a statistically significant increase in weather-related mortality risk with decreasing quartile of median income in all models (not shown).



[1]Deaths attributed to exposure to excessive natural heat (X30) (underlying or contributing cause of death or both), to heat stroke or sunstroke (T67) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.
[2]Deaths attributed to exposure to excessive natural cold (X31) (underlying or contributing cause of death or both), to hypothermia (T68) (contributing cause of death), or to both, according to the *International Classification of Diseases*, *10th Revision*.
SOURCE: CDC/NCHS, National Vital Statistics System, 2006–2010.

Figure 2. Age-adjusted death rates for heat-related and cold-related mortality, by region and urbanization level: United States, 2006–2010

Conclusions

Based on information from death certificates, 10,649 deaths were attributed to weather-related causes in the United States during 2006–2010. Nearly one-third of the deaths were attributed to excessive natural heat, and almost two-thirds were attributed to excessive natural cold. Weather-related death rates differed among demographic subgroups, regions, and counties at different urbanization levels and in different income quartiles. This study found, as studies for earlier time periods have reported, that older persons, males, and non-Hispanic black persons had higher weather-related mortality rates than other ages, females, and other race and ethnicity subgroups.

This study also found that weather-related death rates were 2 to 7 times as high in low-income counties as in high-income counties; however, because only 6% of the population resides in the lowest-income counties and 59% resides in the highest-income counties, a larger number of heat-related and cold-related deaths occurred in the high-income counties (about one-half of the heat-related deaths and one-third of the cold-related deaths). The most urban counties and the most rural counties had the highest heat-related death rates; the most rural counties had the highest cold-related and flood-storm-lightning-related death rates. In regression models, adjustment for urbanization level and region modified associations between weather-related mortality and demographic characteristics and county income.

The differentials in weather-related mortality by demographic characteristics observed for 2006–2010 were consistent with findings for earlier time periods (15,31,37,38). Among adults, heat-related and cold-related death rates increased with age, particularly for those aged 75 and over. Age-adjusted weather-related death rates for males were higher than those for females, and age-adjusted death rates for heat-related and cold-related mortality were higher for non-Hispanic black than non-Hispanic white or Hispanic persons. However, age-adjusted death rates attributed to floods, storms, or lightning were almost twice as high for non-Hispanic white persons compared with non-Hispanic black persons.

The finding that weather-related mortality increased as median county income quartiles decreased may indicate that lower-income areas have fewer resources to prepare for and adapt to extreme weather events (e.g., opening cooling stations during heat waves or insufficient infrastructure to deal with blizzard conditions). It is also possible that individuals with lower incomes in weather-struck areas lack adaptive measures (e.g., air conditioning or heating), thereby making them more susceptible to weather-related mortality (3,9,68).

This study demonstrated the importance of considering urban-rural and regional differentials in weather-related mortality. The study found commonalities in the urban-rural patterns across the country, but also differences. Cold-related mortality and flood-storm-lightning-related mortality were substantially higher in the most rural counties of all regions than in counties at other urbanization levels. The urban-rural patterns observed in the cold-related death rates in the Midwest, Northeast, and South were similar, whereas the pattern observed in the West was distinctly different, and the rates in the West for the small metropolitan, micropolitan, and noncore counties were higher than those in the other regions. For all regions, heat-related mortality was higher in the most urban counties (central counties of large metropolitan areas) than in other metropolitan or micropolitan counties, and similar to those in the most rural counties. Thus, while the urban heat island effect and other characteristics of the highly populated large central metro areas makes residents of large cities highly susceptible to heat-related mortality, populations at other urbanization levels, particularly the most rural populations, are also vulnerable.

The results of the logistic regression models further emphasized the importance of adjusting for urbanization level and region when studying weather-related mortality. Controlling for urbanization level and census region modified associations between heat-related and cold-related mortality and race and ethnicity, and between weather-related mortality and county median household income. For example, the risk of heat-related death among Hispanic persons compared with non-Hispanic white persons was attenuated and was no longer significant after adjustment for urbanization level and region.

This study had some methodological limitations. The number of deaths attributed to weather, particularly heat and cold, is likely underreported (12,15). It is possible that some heat-related and cold-related deaths were not attributed to these causes because they did not meet standard criteria for reporting, or the environmental circumstances at the time of death were unknown. Attribution of deaths to weather-related causes may be subject to bias or misclassification because awareness among individuals completing death certificates may differ across geographic areas (e.g., regions or states) or by characteristics of geographic areas (e.g., urbanization level or income). Deaths resulting from preexisting health conditions (such as heart disease or chronic obstructive pulmonary disorder) exacerbated by extreme temperatures, or from hypersensitivity to extreme temperatures due to use of certain types of medications may not be attributed to heat or cold on the death certificate.

The differences in weather-related mortality observed among demographic subgroups in the United States during 2006–2010 were consistent with those observed in previous national studies (15,31). Examination of weather-related mortality patterns by county median household income, urbanization level, and region demonstrated that a better understanding of subpopulations at risk can be obtained by including such area-based variables in weather-related mortality studies.

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Table 1. Number of deaths with a weather-related cause listed as the underlying cause of death only, as a contributing cause of death only, or both: United States, 2006–2010

Weather event and ICD–10 code listed on death certificate	Cause of death listed as the underlying cause of death only		Cause of death listed as a contributing cause of death only		Any mention	
	N	Percent	*N*	Percent	*N*	Percent
Heat-related deaths[1]	2,027	61	1,305	39	3,332	100
X30 only	13	38	21	62	34	100
X30 and T67[2]	2,014	66	1,032	34	3,046	100
T67 only	. . .	. . .	252	100	252	100
Cold-related deaths[3]	3,192	48	3,468	52	6,660	100
X31 only	252	41	362	59	614	100
X31 and T68[2]	2,940	53	2,605	47	5,545	100
T68 only	. . .	. . .	501	100	501	100
Flood, storm, and lightning[4]	646	98	16	2	662	100
X38 (flood)	93	99	1	1	94	100
X37 (storm)	371	97	10	3	381	100
X33 (lightning)	182	97	5	3	187	100

. . . Category not applicable.

[1]Deaths attributed to exposure to excessive natural heat (X30) (underlying or contributing cause of death or both), to heatstroke or sunstroke (T67) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[2]The ICD–10 codes T67 and T68 can only be contributing causes, not the underlying cause of death. T68 is often mentioned on the death certificate with code X31; T67 is often mentioned on the death certificate with code X30.

[3]Deaths attributed to exposure to excessive natural cold (X31) (underlying or contributing cause of death or both), to hypothermia (T68) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[4]Deaths attributed to exposure to floods (X38), cataclysmic storms (X37), or lightning (X33) (underlying or contributing cause of death or both), according to the *International Classification of Diseases, 10th Revision*.

NOTE: ICD–10 is International Classification of Diseases, 10th Revision.

Table 2. Death counts and death rates (per million resident population) for weather-related mortality, by age: United States, 2006–2010

Age group (years)	Heat-related deaths[1]			Cold-related deaths[2]			Flood-storm-lightning-related deaths[3]			All weather-related deaths[4]		
	Number of deaths	Death rate	Standard error	Number of deaths	Death rate	Standard error	Number of deaths	Death rate	Standard error	Number of deaths	Death rate	Standard error
All ages	3,340	2.1	0.0	6,652	4.2	0.1	662	0.4	0.0	10,649	6.7	0.1
Under 1[5]	86	4.2	0.5	20	1.0	0.2	*	*	*	110	5.4	0.5
1–4[5]	147	1.8	0.2	29	0.4	0.1	*	*	*	187	2.3	0.2
5–14[5]	28	0.1	0.0	39	0.2	0.0	58	0.2	0.0	110	0.5	0.1
15–24	106	0.5	0.1	286	1.3	0.1	97	0.4	0.1	488	2.3	0.1
25–34	186	0.9	0.1	358	1.8	0.1	71	0.4	0.0	615	3.1	0.1
35–44	338	1.6	0.1	711	3.4	0.1	79	0.4	0.0	1,128	5.4	0.2
45–54	619	2.8	0.1	1,301	5.9	0.2	126	0.6	0.1	2,044	9.2	0.2
55–64	545	3.2	0.1	1,097	6.4	0.2	89	0.5	0.1	1,730	10.1	0.2
65–74	463	4.5	0.2	773	7.6	0.3	62	0.6	0.1	1,298	12.7	0.4
75–84	490	7.5	0.3	1,010	15.5	0.5	53	0.8	0.1	1,553	23.8	0.6
85 and over	332	12.8	0.7	1,028	39.6	1.2	27	1.0	0.2	1,386	53.4	1.4

0.0 Quantity more than zero but less than 0.05.

* Figure does not meet standards of reliability or precision.

[1]Deaths attributed to exposure to excessive natural heat (X30) (underlying or contributing cause of death or both), to heatstroke or sunstroke (T67) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[2]Deaths attributed to exposure to excessive natural cold (X31) (underlying or contributing cause of death or both), to hypothermia (T68) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[3]Deaths attributed to exposure to floods (X38), cataclysmic storms (X37), or lightning (X33) (underlying or contributing cause of death or both), according to the *International Classification of Diseases, 10th Revision*.

[4]Deaths attributed to exposure to natural heat (X30), or exposure to natural cold (X31), flood (X38), cataclysmic storm (X37), or lightning (X33) as the underlying or contributing causes of death, according to the *International Classification of Diseases, 10th Revision*.

[5]Due to small death counts, flood-storm-lightning-related deaths for age groups under 1 year, 1–4, and 5–14 years have been combined, and only figures for ages 0–14 years are shown.

Table 3. Death counts and age-adjusted death rates (per million resident population) for weather-related causes, by sex, race and Hispanic origin, region, urbanization level, and income: United States, 2006–2010

Characteristic	Heat-related deaths[1]			Cold-related deaths[2]			Flood-storm-lightning-related deaths[3]			All weather-related deaths[4]		
	Number of deaths	Death rate	Standard error	Number of deaths	Death rate	Standard error	Number of deaths	Death rate	Standard error	Number of deaths	Death rate	Standard error
Sex												
Female	1,029	1.2	0.0	2,128	2.4	0.0	243	0.3	0.1	3,396	3.8	0.1
Male	2,303	3.1	0.0	4,532	6.3	0.1	419	0.6	0.1	7,253	10.0	0.1
Race and Hispanic origin[5]												
Hispanic or Latino	380	2.2	0.1	343	2.1	0.1	20	0.2	0.0	773	4.6	0.2
White, not Hispanic or Latino	2,067	1.8	0.0	4,833	4.1	0.1	541	0.5	0.0	7,436	6.4	0.1
Black, not Hispanic or Latino	747	4.7	0.2	916	5.8	0.2	56	0.3	0.0	1,719	10.8	0.3
Region												
Northeast	324	1.1	0.0	1,211	3.9	0.1	37	0.1	0.0	1,572	5.1	0.1
Midwest	462	1.3	0.0	1,849	5.2	0.1	161	0.5	0.1	2,472	7.0	0.1
South	1,432	2.5	0.0	1,845	3.2	0.1	400	0.7	0.1	3,675	6.4	0.1
West	1,114	3.2	0.0	1,755	5.0	0.1	64	0.2	0.0	2,930	8.3	0.2
Urbanization level[6]												
Large central metro	1,356	3.1	0.0	1,398	3.2	0.1	67	0.2	0.0	2,821	6.4	0.1
Large fringe metro	488	1.3	0.0	1,076	2.8	0.1	121	0.3	0.0	1,684	4.4	0.1
Medium metro	554	1.8	0.0	1,270	4.0	0.1	98	0.3	0.0	1,918	6.0	0.1
Small metro	327	2.2	0.1	835	5.5	0.1	67	0.4	0.1	1,229	8.1	0.2
Micropolitan (nonmetropolitan)	319	1.9	0.1	997	5.9	0.1	150	0.9	0.1	1,465	8.7	0.2
Noncore (nonmetropolitan)	288	2.6	0.1	1,084	9.8	0.2	162	1.6	0.1	1,532	14.0	0.4
Median household income[7]												
$49,241 or above	1,658	1.8	0.0	2,957	3.2	0.1	187	0.2	0.1	4,800	5.3	0.1
$42,408–$49,240	801	2.1	0.0	1,810	4.6	0.1	168	0.4	0.1	2,778	7.2	0.1
$36,518–$42,407	554	3.1	0.1	1,196	6.6	0.1	164	1.0	0.2	1,913	10.6	0.3
$36,517 or below	319	3.2	0.1	697	7.1	0.2	143	1.5	0.3	1,158	11.8	0.4

0.0 Quantity more than zero but less than 0.05.

[1]Deaths attributed to exposure to excessive natural heat (X30) (underlying or contributing cause of death or both), to heatstroke or sunstroke (T67) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[2]Deaths attributed to exposure to excessive natural cold (X31) (underlying or contributing cause of death or both), to hypothermia (T68) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[3]Deaths attributed to exposure to floods (X38), cataclysmic storms (X37), or lightning (X33) (underlying or contributing cause of death or both), according to the *International Classification of Diseases, 10th Revision*.

[4]Deaths attributed to exposure to excessive natural heat (X30), heatstroke or sunstroke (T67), excessive natural cold (X30), hypothermia (T68), floods (X38), cataclysmic storms (X37), lightning (X33) (causes of death), or all, according to the *International Classification of Diseases, 10th Revision*.

[5]Deaths for origin not stated are not included.

[6]Based on 2006 NCHS Urban-Rural Classification Scheme for Counties.

[7]Based on 2008 county median household income quartiles.

NOTES: NCHS is National Center for Health Statistics. Death counts and rates by region, urbanization level, and median income are by place of occurrence. Death rates for Hispanic persons should be interpreted with caution because of inconsistencies in reporting race and ethnicity on death certificates, compared with such reporting on censuses and surveys.

Table 4. Death counts and age-adjusted death rates (per million resident population) for heat-related and cold-related causes, by region and urbanization level: United States, 2006–2010

Region and urbanization level[3]	Heat-related deaths[1]			Cold-related deaths[2]		
	Number of deaths	Death rate	Standard error	Number of deaths	Death rate	Standard error
Northeast						
Large central metro	164	1.9	0.2	324	3.8	0.2
Large fringe metro	82	0.7	0.1	310	2.7	0.2
Medium metro	44	0.8	0.1	291	4.5	0.3
Small metro	*	0.6	0.2	75	5.1	0.6
Micropolitan (nonmetropolitan)	17	0.8	0.2	133	6.0	0.5
Noncore (nonmetropolitan)	*	1.1	0.4	78	9.2	1.1
Midwest						
Large central metro	159	2.1	0.2	417	5.4	0.3
Large fringe metro	88	1.1	0.1	265	3.3	0.2
Medium metro	54	0.9	0.1	316	5.1	0.3
Small metro	37	0.9	0.1	232	5.3	0.4
Micropolitan (nonmetropolitan)	69	1.4	0.2	265	5.1	0.3
Noncore (nonmetropolitan)	55	1.5	0.2	354	9.5	0.5
South						
Large central metro	384	3.2	0.2	356	3.0	0.2
Large fringe metro	220	1.6	0.1	360	2.5	0.1
Medium metro	274	2.2	0.1	369	2.9	0.2
Small metro	179	2.9	0.2	219	3.5	0.2
Micropolitan (nonmetropolitan)	190	2.7	0.2	269	3.7	0.2
Noncore (nonmetropolitan)	185	3.6	0.3	272	5.0	0.3
West						
Large central metro	649	4.0	0.2	301	1.8	0.1
Large fringe metro	98	2.0	0.2	141	3.0	0.3
Medium metro	182	2.7	0.2	294	4.3	0.3
Small metro	102	3.3	0.3	309	10.0	0.6
Micropolitan (nonmetropolitan)	43	1.7	0.3	330	12.9	0.7
Noncore (nonmetropolitan)	40	3.0	0.5	380	30.9	1.6

* Figure does not meet standards of reliability or precision.

[1]Deaths attributed to exposure to excessive natural heat (X30) (underlying or contributing cause of death or both), to heatstroke or sunstroke (T67) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[2]Deaths attributed to exposure to excessive natural cold (X31) (underlying or contributing cause of death or both), to hypothermia (T68) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[3]Urbanization level is based on the 2006 NCHS Urban-Rural Classification Scheme for Counties.

NOTES: NCHS is National Center for Health Statistics. Death counts and rates by region and urbanization level are by place of occurrence.

Table 5. Risk of weather-related death adjusted for selected variables: United States, 2006–2010

Characteristic	Heat-related deaths[1]						Cold-related deaths[2]						Flood-storm-lightning-related deaths[3]					
	Model 1[4]			Model 2[5]			Model 1[4]			Model 2[5]			Model 1[4]			Model 2[5]		
	OR	95%	CI	OR	95%	CI	OR	95%	CI	OR	95%	CI	OR	95%	CI	OR	95%	CI
Age (years)																		
Under 1	4.4	3.4	5.7	4.5	3.5	5.8	0.6	0.4	0.9	0.5	0.3	0.9	0.6	0.2	1.5	0.5	0.2	1.5
1–4	1.9	1.5	2.4	1.9	1.6	2.4	0.2	0.1	0.3	0.2	0.1	0.3	0.4	0.2	0.7	0.4	0.2	0.7
5–14	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.6	0.4	0.9	0.6	0.4	0.8
15–24	0.5	0.4	0.6	0.5	0.4	0.7	0.7	0.6	0.8	0.7	0.6	0.8	1.2	0.9	1.6	1.2	0.9	1.6
25–34 (reference group)	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .
35–44	1.7	1.5	2.1	1.8	1.5	2.1	1.9	1.7	2.2	1.9	1.7	2.2	1.0	0.7	1.4	1.0	0.7	1.4
45–54	3.1	2.6	3.7	3.2	2.7	3.7	3.2	2.9	3.6	3.2	2.8	3.6	1.5	1.1	2.0	1.5	1.1	1.9
55–64	3.7	3.1	4.3	3.7	3.1	4.4	3.5	3.1	3.9	3.4	3.0	3.8	1.3	0.9	1.7	1.2	0.9	1.7
65–74	5.3	4.5	6.3	5.4	4.5	6.4	4.1	3.6	4.6	4.0	3.5	4.5	1.4	1.0	2.0	1.3	1.0	1.9
75–84	9.5	8.0	11.3	9.3	8.1	11.4	8.9	7.9	10.1	8.8	7.8	9.9	1.9	1.3	2.7	1.9	1.3	2.7
85 and over	18.2	15.2	21.9	18.3	15.2	21.9	25.6	22.7	29.0	25.0	22.2	28.3	2.6	1.6	4.0	2.6	1.6	4.1
Sex																		
Female (reference group)	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .
Male	2.7	2.5	2.9	2.7	2.5	2.9	2.6	2.5	2.8	2.6	2.5	2.8	1.8	1.6	2.2	1.8	1.6	2.1
Race and Hispanic origin																		
Hispanic or Latino	1.3	1.1	1.4	0.9	0.8	1.0	0.5	0.5	0.6	0.6	0.5	0.7	0.5	0.4	0.7	0.6	0.5	0.9
White, not Hispanic or Latino (reference group)	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .
Black, not Hispanic or Latino	2.5	2.3	2.7	2.3	2.1	2.5	1.3	1.3	1.4	1.7	1.6	1.9	0.5	0.4	0.7	0.6	0.4	0.7
Median household income[6]																		
$49,241 or above (reference group)	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .	1.0	. . .	. . .
$42,408–$49,240	1.1	1.0	1.1	1.3	1.2	1.5	1.5	1.4	1.6	1.2	1.1	1.3	2.1	1.7	2.6	1.7	1.3	2.1
$36,518–$42,407	1.6	1.5	1.8	2.2	1.9	2.5	2.0	1.9	2.2	1.5	1.4	1.6	4.3	3.5	5.3	2.6	2.0	3.4
$36,517 or below	1.6	1.4	1.8	2.1	1.8	2.5	2.2	2.0	2.4	1.8	1.6	2.0	7.4	5.9	9.2	3.2	2.3	4.3

. . . Category not applicable.

[1]Deaths attributed to exposure to excessive natural heat (X30) (underlying or contributing cause of death or both), to heatstroke or sunstroke (T67) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[2]Deaths attributed to exposure to excessive natural cold (X31) (underlying or contributing cause of death or both), to hypothermia (T68) (contributing cause of death), or to both, according to the *International Classification of Diseases, 10th Revision*.

[3]Deaths attributed to exposure to floods (X38), cataclysmic storms (X37), or lightning (X33) (underlying or contributing cause of death or both), according to the *International Classification of Diseases, 10th Revision*.

[4]Adjusted for age, sex, race and Hispanic origin, and county median household income quartile.

[5]Adjusted for age, sex, race and Hispanic origin, county median household income quartile, region, and urbanization level.

[6]Based on 2008 county median household income quartiles.

NOTES: OR is odds ratio. CI is confidence interval. Deaths with origin not stated were excluded. Death counts and rates by region, urbanization level, and median income are by place of occurrence. Death rates for Hispanic persons should be interpreted with caution because of inconsistencies in reporting race and ethnicity on death certificates, compared with such reporting on censuses and surveys.

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