Heat-Related Deaths

Identification

1. Indicator Description

Extreme heat events (i.e., heat waves) have become more frequent in the United States in recent decades (see the High and Low Temperatures indicator), and studies project that the frequency and intensity of extreme heat events will continue to increase because of climate change (Marvel et al., 2023). When people are exposed to extreme heat, they can suffer from potentially deadly heat-related illnesses such as heat exhaustion and heat stroke. Additionally, the incidence of deaths due to cardiovascular disease (CVD) has been shown to increase with temperature, particularly among older adults and other vulnerable populations such as non-Hispanic Black people (Berko et al., 2014; Zanobetti et al., 2012). Thus, as extreme heat events increase, the risk of heat-related deaths and illness is also expected to increase (Hayden et al., 2023). Tracking the rate of reported overall heat-related deaths and heat-related CVD deaths over time provides a measure of how climate change may affect human well-being.

Components of this indicator include:

- The rate of U.S. annual deaths between 1979 and 2022 for which heat was classified on death certificates as the underlying (direct) cause (Figure 1, orange line).
- The rate of U.S. summer deaths between 1999 and 2021 for which heat was classified as either the underlying cause or a contributing factor (Figure 1, blue line).
- The rate of U.S. summer deaths between 1999 and 2022 for which cardiovascular disease was classified as the underlying cause and heat was listed as a contributing factor (Figure 2). Rates are shown for three groups: the general population, individuals age 65 and older, and non-Hispanic Black individuals.

2. Revision History

April 2010:	Indicator published.
December 2012:	Updated indicator with data through 2009. Added contributing factors analysis to complement the existing time series, converted the measure from counts to crude rates, and added an example figure.
May 2014:	Updated indicator with data through 2010.
June 2015:	Updated indicator with data through 2013.
August 2016:	Updated indicator with data through 2014. Added Figure 2 to show heat-related CVD death rates.
April 2021:	Updated indicator with data through 2018.
June 2024:	Updated indicator with data through 2021 (Figure 1 “underlying and contributing causes”) and 2022 (all other components).

Data Sources

3. Data Sources

This indicator is based on data from the U.S. Centers for Disease Control and Prevention's (CDC's) National Vital Statistics System (NVSS), which compiles information from death certificates for nearly every death in the United States. The NVSS is the most comprehensive source of mortality data for the population of the United States. CDC provided analysis of NVSS data.

Mortality data for the illustrative example figure came from CDC's National Center for Health Statistics (NCHS). The estimate of deaths in excess of the average daily death rate is from the National Research Council's report on climate stabilization targets (NRC, 2011), which cites the peer-reviewed publication Kaiser et al. (2007).

For reference, the illustrative example also shows daily maximum temperature data from the weather station at the Chicago O'Hare International Airport (GHCND:USW00094846).

4. Data Availability

Underlying Causes

The long-term time series (1979–2022) in Figure 1 is based on data from CDC's WONDER online database at: https://wonder.cdc.gov. CDC WONDER provides free public access to mortality statistics, allowing users to query data for the nation as a whole or by state or region, demographic group (age, sex, race), or International Classification of Diseases (ICD) code. Users can obtain the data for this indicator by accessing CDC WONDER and querying the ICD codes listed in Section 5 for the entire U.S. population. Specifically, this component of the indicator uses data from the "Underlying Cause of Death" files at: https://wonder.cdc.gov/Deaths-by-Underlying-Cause.html:

- Compressed mortality for 1979–1998
- Underlying cause of death by bridged-race categories for 1999–2017
- Underlying cause of death by single-race categories for 2018–2022

These three sources reflect the evolution of CDC's reporting and classification systems. The underlying sources are available for overlapping years; in each such year, EPA chose the newer version.

Underlying and Contributing Causes

The 1999–2021 time series in Figure 1 is based on an analysis developed by the National Environmental Public Health Tracking (EPHT) Program, which CDC coordinates. Monthly totals by state are available online at: https://ephtracking.cdc.gov, but these data cannot be used to tabulate national totals because numbers are withheld in states with a low number of cases. CDC has also provided multi-year summary statistics on certain occasions, such as the 2004–2018 article at: www.cdc.gov/mmwr/volumes/69/wr/mm6924a1.htm. CDC staff from the National Center for Environmental Health (NCEH) EPHT branch provided annual national totals to EPA in June 2024.

Users can query underlying and contributing causes of death through CDC WONDER's "Multiple Cause of Death" file (https://wonder.cdc.gov/mcd-icd10.html and: https://wonder.cdc.gov/mcd-icd10-

expanded.html), but note that EPHT performed additional steps for Figure 1 that cannot be recreated through the publicly available data portal (see Section 6).

Underlying and Contributing Causes: Cardiovascular Disease

The 1999–2022 trend lines for heat-related CVD deaths in Figure 2 are based on underlying causes (diseases of the circulatory system) and contributing causes (heat) data from CDC's "Multiple Cause of Death" file, which can be accessed through the CDC WONDER online database. Data for 1999–2017 came from the Bridged-Race Categories data set at: https://wonder.cdc.gov/mcd-icd10.html. Data for 2018–2022 came from the newer Single-Race Categories data set at: https://wonder.cdc.gov/mcd-icd10-expanded.html.

Death Certificates

Individual-level data (i.e., individual death certificates) are not publicly available due to confidentiality issues.

Chicago Heat Wave Example

Data for the example figure are based on CDC's "Compressed Mortality" file, which can be accessed through the CDC WONDER online database at: https://wonder.cdc.gov. The analysis was obtained from Kaiser et al. (2007). Daily maximum temperature data for 1995 from the Chicago O'Hare International Airport weather station are available from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information at: www.ncei.noaa.gov/cdo-web.

Methodology

5. Data Collection

This indicator is based on causes of death as reported on death certificates. A death certificate typically provides space to designate an immediate cause of death along with up to 20 contributing causes, one of which will be identified as the underlying cause of death. The World Health Organization defines the underlying cause of death 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."

Causes of death are certified by a physician, medical examiner, or coroner, and are classified according to a standard set of codes called the ICD. Deaths for 1979 through 1998 are classified using the Ninth Revision of ICD (ICD-9). Deaths for 1999 and beyond are classified using the Tenth Revision (ICD-10).

Although causes of death rely to some degree on the judgment of the physician, medical examiner, or coroner, the "measurements" for this indicator are expected to be generally reliable based on the medical knowledge required of the "measurer" and the use of a standard classification scheme based on widely accepted scientific definitions. When more than one cause or condition is entered, the underlying cause is determined by the sequence of conditions on the certificate, provisions of the ICD, and associated selection rules and modifications.

Mortality data are collected for the entire population and, therefore, are not subject to sampling design error. For virtually every death that occurs in the United States, a physician, medical examiner, or

coroner certifies the causes of death on an official death certificate. State registries collect these death certificates and report causes of death to the NVSS. NVSS's shared relationships, standards, and procedures form the mechanism by which the CDC collects and disseminates the nation's official vital statistics.

Standard forms for the collection of data and model procedures for the uniform registration of death events have been developed and recommended for state use through cooperative activities of the states and CDC's NCHS. All states collect a minimum data set specified by NCHS, including underlying causes of death and basic demographic data (e.g., age, race, and ethnicity). CDC has published procedures for collecting vital statistics data (CDC, 1995).

This indicator excludes deaths to foreign residents and deaths to U.S. residents who died abroad.

General information regarding data collection procedures can be found in the Model State Vital Statistics Act and Regulations (CDC, 1995). For additional documentation on the CDC WONDER database (EPA's data source for part of this indicator) and its underlying sources, see: https://wonder.cdc.gov/wonder/help/main.html.

CDC has posted a recommended standard certificate of death online at: www.cdc.gov/nchs/data/dvs/DEATH11-03final-ACC.pdf. For a complete list and description of the ICD codes used to classify causes of death, see: https://icd.who.int/browse10/2019/en.

Chicago Heat Wave Example

The mortality data set shown in the example figure includes the entire Standard Metropolitan Statistical Area for Chicago, a region that contains Cook County plus a number of counties in Illinois and Indiana, from June 1 to August 31, 1995.

In the text box above the example figure, values reflect data from Cook County only. The number of deaths classified as "heat-related" on Cook County death certificates between July 11 and July 27, 1995, was reported to CDC by the Cook County Medical Examiner's Office. More information is available in CDC's *Morbidity and Mortality Weekly Report* (www.cdc.gov/MMWR/preview/mmwrhtml/00038443.htm). Deaths in excess of the average daily death rate for Cook County were determined from death certificates obtained from the Illinois Department of Public Health (Kaiser et al., 2007).

6. Indicator Derivation

This indicator reports annual rates of deaths per million population that have been classified with ICD codes related to exposure to natural sources of heat. The NVSS collects data on virtually all deaths that occur in the United States, meaning the data collection mechanism already covers the entire target population. Thus, it was not necessary to extrapolate the results on a spatial or population basis. No attempt has been made to reconstruct trends prior to the onset of comprehensive data collection, and no attempt has been made to project data forward into the future.

Underlying Causes

The long-term trend line in Figure 1 reports the rate of deaths per year for which the underlying cause had one of the following ICD codes:

- ICD-9 code E900: “excessive heat—hyperthermia”—specifically subpart E900.0: “due to weather conditions.”

- ICD-10 code X30: “exposure to excessive natural heat—hyperthermia.”

This component of the indicator is reported for the entire year. EPA developed this analysis based on the publicly available data compiled by CDC WONDER. EPA chose to use crude death rates rather than death counts because rates account for changes in total population over time. Population figures are obtained from CDC WONDER.

Underlying and Contributing Causes

The “underlying and contributing causes” trend line in Figure 1 reports the rate of deaths for which either the underlying cause or the contributing causes had one or more of the following ICD codes:

- ICD-10 code X30: “exposure to excessive natural heat—hyperthermia.”

- ICD-10 codes T67.0 through T67.9: “effects of heat and light.” Note that the T67 series is used only for contributing causes—never for the underlying cause.

To reduce the chances of including deaths that were incorrectly classified, EPHT did not count the following deaths:

- Deaths occurring during colder months (October through April). Thus, the analysis is limited to May–September.

- Any deaths for which the ICD-10 code W92, “exposure to excessive heat of man-made origin,” appears in any cause field. This step removes certain occupation-related deaths.

Foreign residents were excluded. EPHT obtained death counts directly from NVSS, rather than using the processed data available through CDC WONDER. EPHT has not yet applied its methods to data prior to 1999. For a more detailed description of EPHT’s analytical methods, see the indicator documentation at: https://ephtracking.cdc.gov/indicatorPages. Crude death rates were calculated in the same manner as with the underlying causes time series.

Underlying and Contributing Causes: Cardiovascular Disease

The lines in Figure 2 report crude rates of deaths for which diseases of the circulatory system were listed as the underlying cause of death and heat was listed as a contributing factor. The underlying causes of death for Figure 2 include the following ICD codes:

- ICD-10 codes I00 through I02: “acute rheumatic fever.”

- ICD-10 codes I05 through I09: “chronic rheumatic heart diseases.”

- ICD-10 codes I10 through I15: “hypertensive diseases.”

- ICD-10 codes I20 through I25: “ischaemic heart disease.”

- ICD-10 codes I26 through I28: “pulmonary heart disease and diseases of pulmonary circulation.”
- ICD-10 codes I30 through I51: “other forms of heart disease.”
- ICD-10 codes I60 through I69: “cerebrovascular disease.”
- ICD-10 codes I70 through I78: “diseases of arteries, arterioles and capillaries.”
- ICD-10 codes I80 through I89: “diseases of veins, lymphatic vessels and lymph nodes.”
- ICD-10 codes I95 through I99: “other and unspecified disorders of the circulatory system.”

To associate diseases of the circulatory system (underlying cause) with heat, the following ICD codes were evaluated as a contributing cause for each death:

- ICD-10 code X30: “exposure to excessive natural heat—hyperthermia.”
- ICD-10 codes T67.0 through T67.9: “effects of heat and light.”

Figure 2 presents data for three demographic groups: the general population, individuals age 65+, and non-Hispanic Black people. Specific query parameters were as follows:

- General population: all races and all age groups.
- Age 65+: all races and the following age groups: 65–74 years, 75–84 years, and 85+ years.
- Non-Hispanic Black people: all age groups, Black or African American race, and not of Hispanic or Latino origin.

EPA queried all data for Figure 2 directly from CDC WONDER at: https://wonder.cdc.gov/mcd-icd10.html and: https://wonder.cdc.gov/mcd-icd10-expanded.html. To reduce the chances of including deaths that were incorrectly classified, EPA removed deaths occurring during colder months (October through April). Thus, the analysis is limited to May–September.

Chicago Heat Wave Example

The authors of Kaiser et al. (2007) determined that the Chicago area had 692 deaths in excess of the background death rate between June 21 and August 10, 1995. This analysis excluded deaths from accidental causes but included 183 deaths from “mortality displacement,” which refers to a decrease in the deaths of individuals who would have died during this period in any case but whose deaths were accelerated by a few days due to the heat wave. This implies that the actual number of excess deaths during the period of the heat wave itself (July 11–27) was higher than 692 but was compensated for by reduced daily death rates in the week after July 27. Thus, the value for excess deaths in Cook County for the period of July 11–27 is reported as approximately 700 in the text box above the example figure.

Indicator Development

During the 2024 update to this indicator, EPA addressed a shift in CDC's mortality reporting from a "bridged-race" classification system to a "single-race" classification. This shift was the result of a change in the categories used to identify an individual's race. These changes were the result of a 1997 federal standard for reporting across federal agencies; it split the "Asian or Pacific Islander" category into two categories and allowed individuals to select more than one race from the list. All jurisdictions that collect or report data for CDC had adopted the new standard by 2018, so CDC has reported mortality data based on the new categories starting with the 2018 data year. This is called the "single-race" data set, and it has five racial groups plus "more than one race." Prior to that, CDC used a "bridged-race" data set that has four racial groups following the pre-1997 standard. For the "bridged-race" data set, CDC had to place multi-racial decedents into a single-race category. Heron (2021) describes these changes in more detail and provides an analysis of their effect on mortality statistics. CDC has made both data sets available for the years 2018–2020, which makes it possible to compare the two data sets for three overlapping years.

EPA's indicator uses the newer "Single-Race" data set starting in 2018, the first year of its availability. EPA reviewed the data to determine what effect, if any, the classification change would have on this indicator. It affects only one component of the indicator: the time series in Figure 2 for non-Hispanic Black people. The death count in each of the three overlapping years is the same in both data sets, which indicates that these same decedents were assigned to the "Black" race category in both data sets. However, the total national non-Hispanic Black population used as a denominator for calculating death rates is approximately 5 percent lower in the newer data set in each of the three overlapping years. This is to be expected, as some fraction of the population previously identified as only "Black" by race can now be correctly classified as "more than one race." This reduction of the denominator has the effect of slightly boosting the resulting death rate. However, it does not alter this indicator's conclusions, as the indicator does not attempt to report a trend for non-Hispanic Black people; the summary text simply states that non-Hispanic Black people have a death rate higher than the general population average, which remains true.

All other components of this indicator use "all races" data, so the change should have no effect. That is, the reclassification did not change the total number of deaths for the general population or by age group, nor did it change the population used as a denominator for calculating rates for these groups. Heron (2021) notes that the reclassification leads to minimal impacts on age-adjusted death rates, but because EPA's indicator uses crude rates that simply depend on the death count and the total population of the group in question, this reclassification has no effect on any part of the indicator where race is not a consideration.

7. Quality Assurance and Quality Control

Vital statistics regulations have been developed to serve as a detailed guide to state and local registration officials who administer the NVSS. These regulations provide specific instructions to protect the integrity and quality of the data collected. This quality assurance information can be found in CDC (1995).

For the "underlying and contributing causes" component of this indicator, extra steps have been taken to remove certain deaths that could reflect a misclassification (see Section 6). These criteria generally excluded only a small number of deaths.

Analysis

8. Comparability Over Time and Space

When plotting the long-term data in Figure 1, EPA inserted a break in the line between 1998 and 1999 to reflect the transition from ICD-9 codes to ICD-10 codes. The change in codes makes it difficult to accurately compare pre-1999 data with data from 1999 and later. Section 6 describes a change in racial classifications that took effect in 2018 but notes that it only affects one line in Figure 2, and arguably not to the extent that would require inserting another discontinuity. Otherwise, all methods have been applied consistently over time and space. ICD codes allow physicians and other medical professionals across the country to use a standard scheme for classifying causes of deaths.

9. Data Limitations

Factors that may impact the confidence, application, or conclusions drawn from this indicator are as follows:

1. It has been well-documented that many deaths associated with extreme heat are not identified as such by the medical examiner and might not be properly coded on the death certificate. In many cases, they might just classify the cause of death as a cardiovascular or respiratory disease. They might not know for certain whether heat was a contributing factor, particularly if the death did not occur during a well-publicized heat wave. By studying how daily death rates vary with temperature in selected cities, scientists have found that extreme heat contributes to far more deaths than the official death certificates would suggest (Medina-Ramón & Schwartz, 2007). That is because the stress of a hot day can increase the chance of dying from a heart attack, other heart conditions, and respiratory diseases such as pneumonia (Kaiser et al., 2007). Deaths from these causes are much more common overall than dying directly from a heat-related illness such as heat stroke. Thus, this indicator very likely underestimates the number of deaths caused by exposure to heat. However, it does serve as a reportable national measure of overall deaths and CVD deaths attributable to heat.

2. ICD-9 codes were used to specify underlying cause of death for the years 1979 to 1998. Beginning in 1999, cause of death was specified with ICD-10 codes. The two revisions differ substantially, so data from before 1999 cannot easily be compared with data from 1999 and later.

3. The fact that a death is classified as “heat-related” does not mean that high temperatures were the only factor that caused the death. Pre-existing medical conditions can greatly increase an individual’s vulnerability to heat.

4. Heat waves are not the only factor that can affect trends in “heat-related” deaths. Other factors include the vulnerability of the population, the extent to which people have adapted to higher temperatures, the local climate and topography, and the steps people have taken to manage heat emergencies effectively. In particular, heat-response measures can make a big difference in death rates. Response measures can include early warning and surveillance systems, air conditioning, increased access to cooling centers, health care, public education, infrastructure standards, and air quality management. For example, after a 1995 heat wave, the city of Milwaukee developed a plan for responding to extreme heat conditions in the

future. During a 1999 heat wave, this plan cut heat-related deaths nearly in half compared with what was expected (Weisskopf et al., 2002).

Other studies may shed some light on the extent of undercounting inherent in this data set. As described in Sarofim et al. (2016), some statistical approaches estimate that more than 1,300 deaths per year in the United States are due to extreme heat, compared with about 750 deaths per year in the "underlying and contributing causes" data set shown in Figure 1. The Chicago heat wave example shows that a single extreme heat event likely caused about 700 deaths that would not otherwise have occurred during that time period, even though only 465 deaths were attributed to extreme heat on death certificates during that period.

10. Sources of Uncertainty

Uncertainty estimates are not available for this indicator. Because statistics have been gathered from virtually the entire target population (i.e., all deaths in a given year), these data are not subject to the same kinds of errors and uncertainties that would be inherent in a probabilistic survey or other type of representative sampling program.

Some uncertainty could be introduced as a result of the professional judgment required of the medical professionals filling out the death certificates, which could result in misclassification or underreporting in some number of cases.

11. Sources of Variability

There is substantial year-to-year variability within the data, due in part to the influence of a few large events. Many of the spikes apparent in Figures 1 and 2 can be attributed to specific severe heat waves occurring in large urban areas.

12. Statistical/Trend Analysis

This indicator does not report on the slope of the apparent trends in heat-related deaths, nor does it calculate the statistical significance of these trends.

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