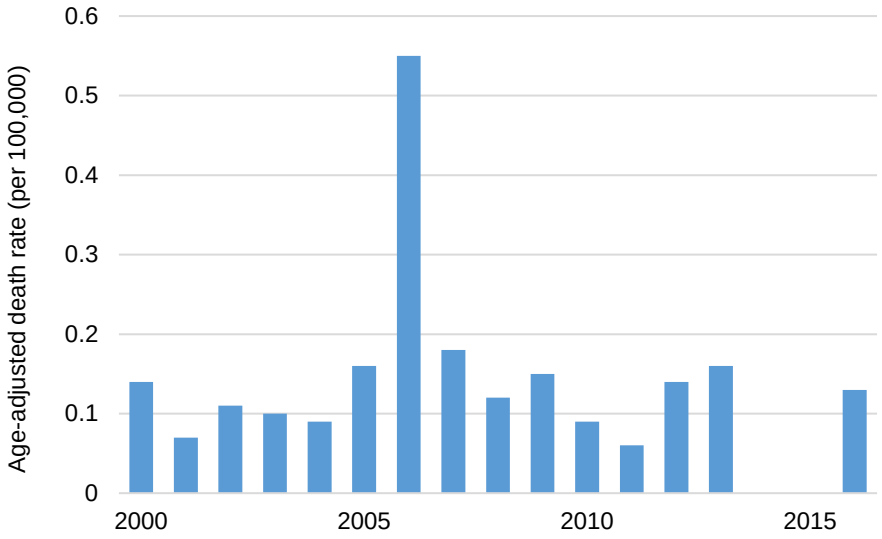
HEAT-RELATED MORTALITY AND MORBIDITY

Deaths and illnesses from heat exposure are severely underreported, and vary from year to year. In 2006, numbers of deaths and illnesses were much higher than any other year because of a prolonged heat wave.

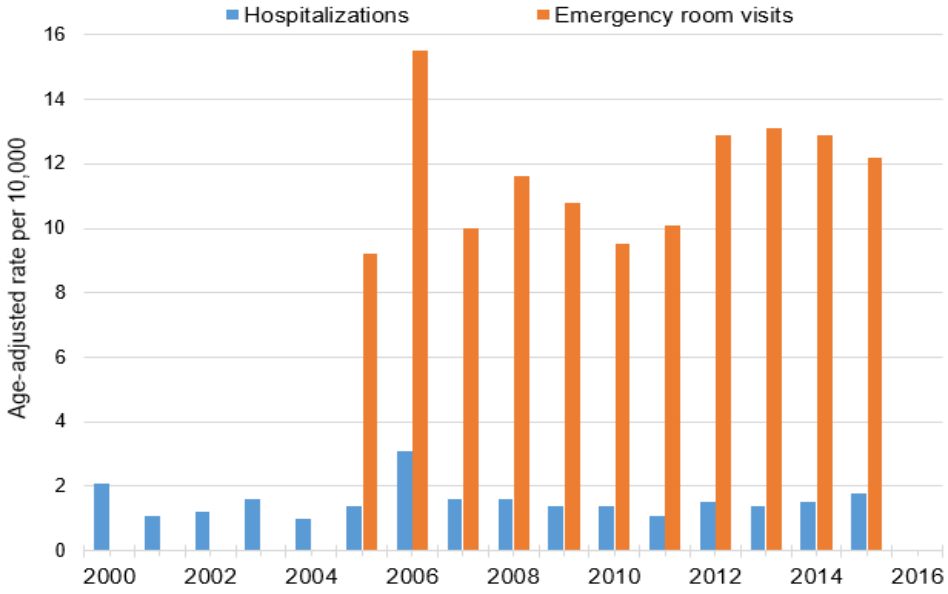
Figure 1. Heat-related deaths



**Mortality data with all causes of death were not available for 2014 and 2015 at the time of analysis*.

Source: Data set compiled by Tracking California,
using data from the Center for Health Statistics (PHI, 2018)

Figure 2. Heat-related illnesses*



**Data for emergency room visits were not available until 2005.*

Source: Data set compiled by Tracking California,
using data from the Office of Statewide Health Planning and Development. (PHI, 2017a)

What does the indicator show?

Exposure to high temperatures can lead to illness (morbidity) and deaths (mortality). Heat-related illnesses are a broad spectrum of diseases, ranging from mild heat cramps to severe, life-threatening heat stroke, to death. Figure 1 presents annual heat-related death rates for 1999 to 2013 and for 2016. (At this time, mortality data for all causes of death are not available for the years 2014 and 2015.) Figure 2 shows both heat-related hospitalizations (2000 to 2015) and heat-related emergency room (ER) visits (2005 to 2015). No trend is evident in either heat-related illnesses or deaths in California, both of which vary from year to year. In 2006, dramatic increases in many heat-related illnesses and deaths were reported following a record-breaking heat wave. Over 16,000 excess emergency room visits, over 1,100 excess hospitalizations (Knowlton et al., 2009), and at least 140 deaths (Margolis et al., 2008) occurred between July 15 and August 1, 2006.

Heat-related illnesses and deaths are often misclassified as another underlying cause or unrecognized. Hence, the available data on heat-related illnesses and deaths likely underestimate the full health impact of exposure to periods of high temperatures, including heat waves.

Why is this indicator important?

Heat causes more reported deaths per year on average in the United States than any other weather hazard, yet heat-related illnesses and deaths are generally preventable (NOAA, 2017; Luber et al., 2014). Certain groups such as infants, children, pregnant women, the elderly, those with pre-existing health conditions, and those who are socioeconomically disadvantaged are especially vulnerable to overexposure to heat (Luber et al., 2014).

Tracking heat-related illnesses and deaths provides critical information for developing adaptation plans and evaluating their successes, especially in relation to heat waves. State and local policies, plans, and programs focusing on heat are already in place in some locations. These may include heat wave early warning and surveillance (observation) systems, accessible cooling centers, public education campaigns on preventing heat-related illnesses, and worker heat-safety regulations. The use of air conditioning has been associated with significant reductions in heat-related hospital visits in California (Ostro et al., 2010). However, during periods of high heat, there is likely to be a greater risk of brownouts or blackouts from overuse of gas and electricity.

Periods of warmer temperatures and heat waves are expected to rise in frequency, duration, and intensity over the next century (IPCC, 2014; Luber et al., 2014). Projections for California estimate about a 10- to 20-fold increase in the number of extremely hot days by the mid-21st century, and about a 20- to 30-fold increase by the end of the century (CCAT, 2013). These projection numbers suggest an increasing public health burden from heat-related deaths and illnesses.

What factors influence this indicator?

Heat-related health outcomes are affected by the magnitude and duration of exposures to heat, as well as by factors relating to the exposed individuals, such as age, health status, and access to air conditioning.

As shown in figures 1 and 2, heat-related illnesses and deaths in 2006 peaked during the prolonged heat wave that occurred from July 16 to 26 (Knowlton et al., 2009; Margolis et al., 2008). Average apparent temperatures ranged from 81°F to 100°F, which is 4°F greater than the average statewide temperatures in July. The Central Valley region had the highest number of uninterrupted hot days ever recorded, with each day reaching 100°F and greater. Multiple locations in California broke records for the highest number of uninterrupted days over 100°F ever recorded: 11 in Sacramento; 12 in Modesto; and 21 in Woodland Hills near Los Angeles (Kozlowski and Edwards, 2007).

As noted above, certain groups are more vulnerable to heat exposure. These include the elderly, young children, people with pre-existing health conditions (such as heart or lung disease), African Americans, socially isolated people, the poor, and those who have difficulty getting medical care (CCAT, 2013; Basu and Ostro, 2008). Those engaged in vigorous physical activity are also at risk, such as workers in construction, firefighting, and agriculture. The rate of occupational heat-related deaths in California slightly exceeds the national average (Gubernot et al., 2016).

Urban residents may be more vulnerable to heat waves than people who live in surrounding suburban and rural areas. Buildings, dark paved surfaces, lack of vegetation and trees and heat emitted from vehicles and air conditioners cause cities to generate and retain heat, a phenomenon known as the “urban heat island effect.” On the other hand, people living in historically cooler areas may be less acclimated to heat than people living in historically warm areas and are less likely to have air conditioners installed in their homes (CDPH, 2007).

Communities with measures to prevent adverse heat-related health effects will likely fare better during times of extreme heat as California continues to warm. Such measures include early warning and surveillance systems, access to air conditioning, and public outreach and education.

Other findings studies on the effect of various factors on heat-related deaths and illnesses are discussed below.

<u>Heat-related deaths</u>

Investigators worldwide have documented relationships between elevated ambient temperature and mortality (Basu, 2009; Anderson and Bell, 2011). Deaths related to the July 2006 heat wave were largely attributed to elevated nighttime temperatures (Gershunov et al., 2009). Minimum temperatures, which reflect nighttime temperatures, have been increasing at a higher rate than daytime temperatures in California (see *Annual air temperature* indicator). In addition, heat waves have become increasingly

more humid since the 1980's. People who are adapted to California's traditionally dry daytime heat and nighttime cooling are less able to recover from extreme heat, especially when humidity levels are high.

Studies conducted in California have also documented increased mortality risk not only with extreme heat events, but also with increasing apparent temperature (Basu and Ostro, 2008; Basu et al., 2008; Basu and Malig, 2011). One California study found deaths from non-accidental causes increased by approximately 2.6 percent for every 10^{o} F increase in mean daily apparent temperature. The effects were acute, with same-day effects being most significant, supporting the notion that public health actions to prevent heat-related mortality should be immediate. The investigators found that these effects not only impacted frail, elderly individuals but a broader population, and therefore, have the potential for greater public health risk.

Heat-related illnesses

Dramatic increases across a wide range of illnesses were observed during the summer of 2006 for emergency department visits, including heat stroke, electrolyte imbalance, acute kidney failure, diabetes, and cardiovascular diseases (Knowlton et al., 2009).

A 2014 study investigated the public health impacts of 19 heat waves throughout six regions of California from 1999 to 2009 (Guirguis et al., 2014). On average, hospital admissions were found to increase by seven percent on the peak heat-wave day, with a significant impact for cardiovascular diseases, respiratory diseases, dehydration, acute renal failure, heat illnesses, and mental health. Statewide, there were 11,000 excess hospitalizations that were due to extreme heat over the study period. The strongest health impacts occurred in the Central Valley and in the north and south coasts, with the north coast disproportionately affected. In the face of more frequent and severe heat waves, public health officials will be tasked with implementing plans to protect the high population areas along the coast, where heat acclimation is poor and air conditioners are less common.

In one study, apparent temperature, a combination of temperature and relative humidity, and hospital admissions were evaluated in nine counties across California from 1999 to 2005 (Green et al., 2010). Significantly increased risk of hospitalizations for multiple diseases, including ischemic heart disease, respiratory diseases, pneumonia, dehydration, heat stroke and diabetes were associated with a 10^{o}F increase in mean daily apparent temperature. Increased mean daily apparent temperature was found to have same-day associations with emergency room admissions for several health outcomes, particularly for certain age and race/ethnic groups, which varied by disease (Basu et al., 2012).

Warming temperatures can increase emergency room visits for mental health-related outcomes, including violence and self-harm (Basu et al., 2017b). Apparent temperature has also been found to be associated with preterm delivery, with younger mothers and Black and Asian mothers at greatest risk (Basu et al., 2010). The week before preterm delivery was found to be associated with the most profound effects. Mothers with pre-

existing and/or gestational diabetes, hypertension, pre-eclampsia, or depression, as well as those who were underweight, Medicaid users, alcohol consumers or smokers were at greater risk for heat-associated preterm delivery (Basu et al., 2017a). Another study has also shown an association between apparent temperature and increase in stillbirths during the warm season two to six days before the fetal loss (Basu et al., 2016). These studies add to the growing body of literature identifying pregnant women and their fetuses as subgroups vulnerable to heat exposure.

Notably, even without extremes in temperatures, investigators observe associations between temperature, deaths, hospital or emergency room admissions, and adverse birth outcomes during the warm season in California (Basu and Ostro, 2008; Basu et al., 2008; Basu et al., 2010; Green et al., 2010; Basu et al., 2012; Basu et al., 2017b).

Technical considerations

Data Characteristics

Heat-related hospitalizations and emergency room visits were identified for the months of May -September by the California Environmental Health Tracking Program (CEHTP, recently renamed “Tracking California”). CEHTP is a program of the Public Health Institute, in partnership with the California Department of Public Health. Heat-related diseases were identified using Incident Classification of Disease (ICD)-9 codes for: heat stroke and sunstroke; heat syncope; heat cramps; heat exhaustion; heat fatigue; heat edema; other specified heat effects; unspecified effects of heat and light; health effect caused by excessive heat due to weather; and effect from unknown cause of excessive heat. Causes that were due to a man-made source of heat were excluded. Hospitalization data were available for the years 2000 to 2015, and data on emergency room visits for the years 2005 to 2015.

CEHTP also identified heat-related deaths for the months of May-September, from 2000 to 2013, and for 2016, using ICD-10 codes for the following causes of death: heat stroke and sun stroke; heat syncope; heat cramps; heat exhaustion; heat fatigue; heat edema; exposure to excessive natural heat; other specified heat effects; and unspecified effects of heat and light. CEHTP did not have access to all causes mortality data for the years 2014 and 2015 at the time of analysis; hence, heat-related deaths for those years could not be identified. As with the morbidity dataset, deaths due to a man-made source of heat were excluded. More information about data and methods, including rate calculations, can be found at the CEHTP website (PHI, 2017b).

Strengths and limitations of the data

As noted earlier, the available data on heat-related illnesses and death likely underestimates the full health impact of exposure to heat. Heat-related health effects can manifest in a number of clinical outcomes, and people with chronic health problems are more susceptible to the effects of heat than healthy individuals. Heat-related illnesses and deaths are often misclassified or unrecognized.

During a heat wave, the number of heat-related deaths from coroners’ reports rely on deaths coded as “heat-related” without any universal classification of these diseases.

Few deaths are recorded on death certificates as being heat-related (English et al., 2009). Heat illness is rarely listed as a main cause of deaths that occur in hospitals or emergency rooms, even when exposure to heat is a contributing factor. It is likely that there were three to four times as many deaths in the July 2006 heat wave than were actually reported (Ostro et al., 2009; Joe et al., 2016).

Despite these known limitations, heat-related health effects are tracked nationally. This data can be used to identify trends in heat-related morbidity and mortality and can be compared across states (US EPA, 2016).

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