[CHAPTER 2]

The Heat Index: What Extreme Heat "Feels Like"

The outside temperature according to a car dashboard may be 90°F, but what we feel when we step out could be worlds apart depending on whether we are parked in Arkansas or Arizona. It is not only hot in Arkansas but also often humid. To our bodies' cooling systems, humidity makes all the difference. People sweat to release heat because when sweat evaporates, it has a cooling effect. A breeze or a fan can help us to cool down by quickening the pace of that evaporation. But humidity in the air around us limits the evaporation of sweat and reduces the associated cooling effect. So high temperature and humidity cause our bodies to accumulate heat. For this reason, temperature is generally considered in tandem with humidity to measure heat stress conditions, or those in which the human body has difficulty cooling itself (CDC 2017b).

When exposed to such conditions, our bodies' temperature rises, and heat-related illnesses (ranging in severity from mild heat cramps to life-threatening heat stroke) can occur. In general, adults over the age of 65, young children, people who are sick, people with mental or physical disabilities, people in low-income communities (who often lack access to air-conditioning or the means to pay for its use), outdoor workers, and military personnel who must exert themselves outdoors are among the most vulnerable to extreme heat, given their greater exposure and/or their bodies' diminished ability to cope (Morris et al. 2019; Reid et al. 2009). Over the last 30 years, on average, exposure to extreme heat was the top cause of weather-related deaths in the United States (NWS 2018). Between 1999 and 2010, exposure to extreme heat was implicated in 7,415 deaths in the United States—an average of more than 600 per year (CDC 2012)—but likely contributed to many more (Berko et al. 2014; Luber and McGeehin 2008; Donoghue et al. 1997).

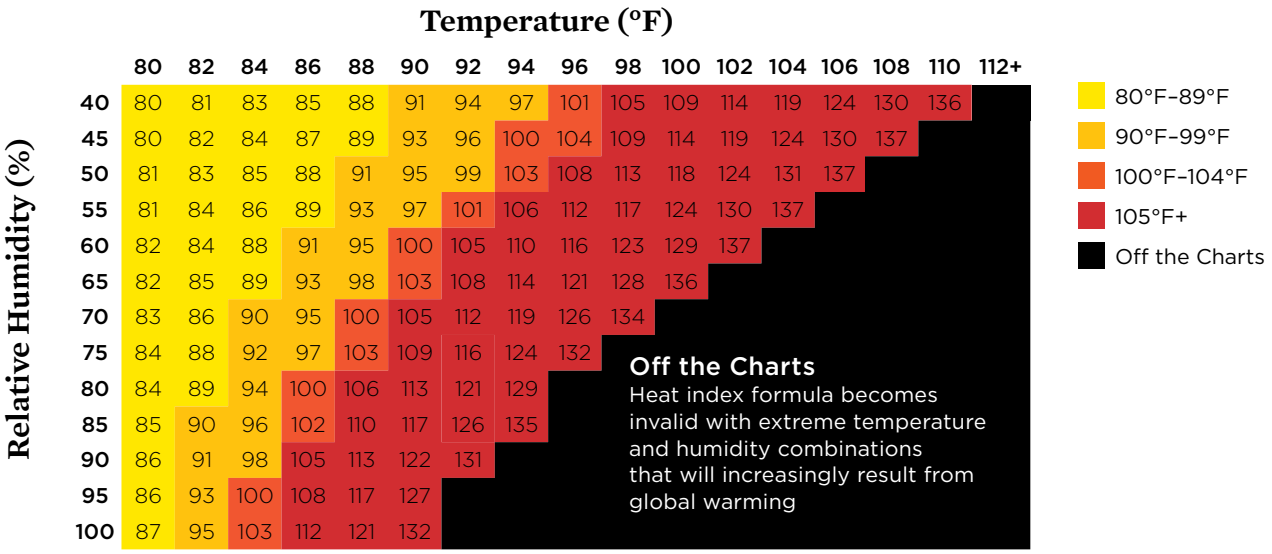
To our bodies' cooling systems, humidity makes all the difference.

To warn people of anticipated or ongoing conditions that could cause heat-related illnesses or death, the NWS combines temperature and relative humidity to produce a heat index, or a "feels like" temperature (NWS n.d. a) (see Figure 1, p. 5, and box, p. 7).[5] The NWS uses heat index–based thresholds as the basis for issuing heat advisories and excessive heat warnings. For example, when relative humidity is low, at 45 percent, a temperature of 94°F would result in a heat index of 100°F. However, at a higher relative humidity of 70 percent, a temperature of only 88°F would result in that same heat index. In humid locations such as Arkansas, the heat index may be much higher than the air temperature, whereas in arid locations such as Arizona, the temperature and heat index may be the same.

How and Why the National Weather Service Uses Heat Index Thresholds

While health risks exist at all heat index values above 80°F, the severity of those risks varies depending on who is exposed, whether they are engaged in physical activity, and how long the exposure lasts (Morris et al. 2019). Conditions that are manageable for some people can be dangerous—or even fatal—for others (Morris et al. 2019; Grundstein et al. 2010). Age, underlying health, physical fitness, access to

FIGURE 1. How Temperature and Humidity Create the Heat Index



Heat is more harmful to human health when humidity is high because humid air hinders the evaporation of sweat, and thus reduces the body's ability to cool itself. To determine the effect of both heat and humidity, the National Weather Service formulated the heat index based on the range of warm-season conditions we typically see on Earth. As our climate warms, we will increasingly find ourselves outside the range of reliably calculable heat index values, or, quite literally, off the charts. Colors reflect the categories of heat index conditions examined in this study.

SOURCE: STEADMAN 1979A; NWS N.D. A.

cooling, and a person's surroundings (e.g., whether they live in a city or a rural environment) are among the many factors that determine overall heat health risks.

When developing its guidance for the use of the heat index in forecasts and alerts in the 1980s, the NWS considered the impacts of a range of heat index values on human health (NWS 1984). The language used by the NWS in heat alerts today reflects both the general risks extreme heat poses to the public and considerations of the groups most at risk during an extreme heat event.

National guidance from NWS suggests, in general, that a local heat advisory be issued when the heat index in a region is expected to reach or exceed 100°F for 48 hours and that an excessive heat warning be issued when the heat index reaches or exceeds 105°F for 48 hours (NWS n.d. b). These thresholds have been established because these conditions can be dangerous, even deadly (see Figure 2, p. 6). While the thresholds are somewhat arbitrary, given that the impacts of heat are highly individual (Watts and Kalkstein 2004), NWS guidance and additional research point to the following:

Conditions that are manageable for some people can be dangerous—or even fatal—for others.

- With a heat index around 90°F, sun stroke, heat cramps, and heat exhaustion are possible for certain risk groups (NWS 1984). In particular, those who engage in physical exertion outdoors (e.g., outdoor workers, military personnel, athletes) without being accustomed to the heat are susceptible to heat stress at this threshold (Morris et al. 2019; OSHA n.d.).
- At a heat index of 100°F, NWS heat advisories state that "heat stress or illnesses are possible, especially for elderly adults and those sensitive to heat," which includes children (Iowa State University 2019). Advice such as "Drink plenty of fluids" and "Check up on relatives and neighbors" frequently accompanies NWS heat advisories at this level.
- At a heat index of 105°F, even healthy adults are at risk of heat-related illness with prolonged exposure. NWS excessive heat warnings issued at this level often state

that "heat illness is likely." Warnings such as "When possible, reschedule strenuous activities to early morning or evening"; "The very young, the elderly, those without air conditioning, and those participating in strenuous outdoor activities will be the most susceptible"; and "Car interiors can reach lethal temperatures in a matter of minutes" usually accompany these alerts (Iowa State University 2019).

- For heat index values above 130°F, NWS has no standard guidance, though one source indicates that heat stroke is "highly likely with continued exposure" (NWS 1984).
- The Occupational Safety and Health Administration (OSHA) advises that exposure to direct sun can increase the heat index by as much as 15 degrees.

Local environmental conditions and the degree to which people are acclimatized—or accustomed—to extreme heat affect health outcomes in different regions. Because of this, nearly half of local NWS Weather Forecast Offices have developed their own revised policies around extreme heat (Hawkins, Brown, and Ferrell 2017).[6] NWS offices in South Carolina, for example, where the population is accustomed to extreme heat, have raised the threshold for excessive heat warnings from 105°F to 115°F. The policies of other local offices include factors such as elevation, nighttime temperatures, and time of year (Hawkins, Brown, and Ferrell 2017).

However, rising numbers of heat-related deaths in places such as Phoenix, Arizona—where we might expect residents to be accustomed to the heat—suggest that warming temperatures and a range of socioeconomic factors (such as access to functional air-conditioning, age, and race) require greater consideration when defining the local risk posed by extreme heat (Maricopa County Public Health 2017; Hayden, Brenkert-Smith, and Wilhelmi 2011; Stone, Hess, and Frumkin 2010). And while access to ubiquitous air-conditioning has been shown to reduce heat-related mortality, true physiological acclimatization to heat requires consistent outdoor daily exertion over an extended period of time. The facts of this process suggest that constant access to air-conditioning may preclude acclimatization (Nordio et al. 2015; Acosta 2009).

In many northern states, where heat-related mortality is more prevalent, incidences of heat-related illness start to rise with a heat index as low as 80°F to 85°F (Vaidyanathan et al.

FIGURE 2. More People Are at Risk as the Heat Index Rises

Left to right: AP Photo/Napa Valley Register, Lianne Milton; AP Photo/Julio Cortez; lzf/iStock; logoboom/Shutterstock

Heat index conditions as low as 80°F can affect human health. Extreme heat exposure affects people differently depending on their health and environment. Certain groups of people may become more susceptible to heat-related illness as the heat index rises.

SOURCES: IOWA STATE UNIVERSITY 2019; MORRIS ET AL. 2019; NWS 1984; NWS N.D. B; OSHA N.D.

AP Photo/Richmond Times-Dispatch, P. Kevin Morley

Extreme heat caused hundreds of cases of heat-related illness during the Boy Scouts of America's 2005 National Jamboree in Virginia. Susceptibility to heat-related illness depends on many factors, including a person's age and fitness and how acclimated they are to extreme heat.

2018; Curriero et al. 2002). Because of this, some individual states and localities have revised their advisory thresholds downward (Wellenius et al. 2017; NHDPHS n.d.). Officials also now consider how long the heat event is expected to last and the time of year it occurs, as heat events occurring earlier in the year, before people are acclimatized to warmth, have a greater impact on human health than those occurring later in the summer or early fall (Sheridan and Lin 2014; Anderson and Bell 2011).

Off-the-Charts Days

The heat index was originally formulated to capture all but the most extreme combinations of temperature and relative humidity occurring on Earth (Steadman 1979a). In heat that exceeds the ranges of the temperature and relative humidity values that were considered, skin moisture levels are so high that sweating is significantly inhibited and the equations used by the National Weather Service (NWS) to calculate the heat index become unreliable (Alber-Wallerström and Holmér 1985) (see Figure 1, p. 5).

Without a reliable estimate of the heat index, the NWS cannot adequately communicate the gravity of associated risks to public health. Historically, such incalculable conditions have represented the world's most oppressively hot, dangerous, and, fortunately, rare days—those with a heat index well above 130°F. The only place in the contiguous United States that has had off-the-charts days in an average year is the Sonoran Desert, where Southern California meets Arizona. Our analysis projects that, as our overall climate warms, this will change.

As global average temperatures continue to warm, driven by our heat-trapping emissions, not only will the frequency of extreme heat events increase (USGCRP 2017), but high heat index conditions will also become more extreme, surpassing dangerous thresholds more frequently and heading—for the first time in most regions—into unprecedented territory holding even greater risk of illness and mortality for residents. Within the next 20 years, many people in the United States will be faced with heat unlike any they have dealt with before.

Those not accustomed to extreme heat conditions are more susceptible to heat-related illness and mortality.