

Short communication

Heat fatalities in Pima county, Arizona

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Abstract

The most common cause of heat fatalities is environmental exposure during heat waves. Deserts of the southwestern USA are known for temperatures that exceed 32 °C for 30 days or more; yet, heat-related fatalities are rare among residents of the region. We compiled data from the National Weather Service and the Office of the Medical Examiner in order to determine the relationship between temperature and occurrence of heat fatalities in Pima County, AZ. Logistic regression indicated that for each degree of increase in temperature (°C), there was a 35% increase in the odds of a heat fatality occurring ($p < 0.001$).

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Introduction

Heatstroke is a potentially fatal disorder that results from extreme elevation of body temperature. The most common cause of heat fatalities in the United States of America (USA) is environmental exposure during heat waves. Heat waves are defined as three or more consecutive days with temperatures that exceed 32 °C (Bouchama, 1995; Bouchama and Knochel, 2002; Kilbourne, 1999; Kilbourne, 2002; Mirchandani et al., 1996; Naughton et al., 2002; Rajpal et al., 2000). Even in heat waves, fatalities occur predominantly in the very young, the elderly, the poor, and the socially isolated.

Exertion, dehydration, comorbid illness, medications, and lack of home air conditioning further increase the risk (Armstrong et al., 1996; Charatan, 2003; Epstein et al., 1999; Jones et al., 1982; Keim et al., 2002; Kilbourne, 1998; Oh and Henning, 2003; Wetterhall et al., 1998). Although typically defined by clinical presentation, Bouchama and Knochel proposed a physiological definition for heat stroke as “a form of hyperthermia associated with a systemic inflammatory response leading to a syndrome of multi-organ dysfunction in which encephalopathy predominates” (Bouchama and Knochel, 2002).

Deserts of the southwestern USA, like those found in the state of Arizona (AZ), are known for temperatures that exceed 32 °C for 30 days or more; yet, heat-related fatalities are rare among residents of the region (Mrela, 2004). Arizona experienced a substantial increase in the

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number of heat fatalities in 2002. The increase has been attributed to the rise in illegal immigration across the Mexican border (Mrela and Humble, 2004). Illegal immigrants are presumed to be at high risk of heatstroke because they may underestimate the scarcity of viable cover from the heat, the length of time they will be exposed, the exertion that will be required to walk across the desert, and the amount of food and water that will be required (Marizco and Ibarra, 2004; Hadden, 2003; Hendricks, 2004). Of the 125 heat fatalities occurring among illegal immigrants in AZ in 2001 and 2002, 79% occurred in Pima County, the largest of the border counties in AZ (most recent statewide data available (Mrela, 2004)). We compiled data from the National Weather Service and the Pima County Medical Examiner in order to determine the relationship between temperature and the occurrence of heat fatalities in Pima County, AZ in 2002 and 2003.

Methods

Daily temperatures

Weather data were obtained from the National Weather Service (NWS). Daily ambient high temperature (DAHT) and heat index were obtained from the five regional reporting stations within Pima County for the years 2002 and 2003. The most complete data for DAHT in 2002 were available from the Tucson station (365 days per year). Available data from the other four stations ranged from 251 to 356 days per year. The correlation between DAHTs in Tucson and those of the other four stations exceeded 0.93 in each case and the difference between the average annual DAHT for Tucson and the other four stations ranged from -0.27 to 0.33 standard deviations. Thus, DAHT data from the Tucson reporting station were used to represent Pima County DAHT in all analyses. Although, the heat index is commonly used at temperatures above 26°C to account for the role played by relative humidity in increasing the perception and impact of high heat, it is not useful in arid climates. Heat index data were available from the Tucson station on 99% of the 227 days in 2002 for which the DAHT exceeded 26°C . The correlation between ambient temperature and heat index was 0.97. On average, the heat index value was lower than the DAHT, not higher as it would commonly be in a less arid climate. It exceeded the DAHT on only 5% of the days. Thus, the unadjusted DAHT was used in all analyses.

Heat fatalities

Anonymous case record data for heat fatalities occurring in Pima County were obtained from the

Office of the Medical Examiner. The University of Arizona Human Subjects Protection Office reviewed and approved the methods used in this study. Case records included the date an individual was hospitalized/rescued or the date a body was discovered, the location of heat exposure (latitude and longitude), description of articles of clothing and other items found on the individual, and the age, gender, and nationality of an individual. The designation of heat fatality was made by a medical examiner (ME) based on autopsy findings, along with the scene and historical information. When the death was not witnessed or reported, the date of the individual's death was estimated by the ME from medical, forensic, and investigative information. The ME's estimate was grouped into date ranges to account for the imprecision of forensic dating. The three ranges were: (a) less than 72 h since death, (b) 72 h to 1 week since death, and (c) greater than 1 week since death.

Estimating the date on which the lethal heat exposure occurred

The following heuristic was used to estimate the date on which the lethal heat exposure (DLE) occurred. The DLE was the day the individual was admitted to the hospital, if (s)he died in the hospital. The DLE was the day the individual was rescued if (s)he died in the field prior to admission to the hospital. When the ME estimated from the remains that death had occurred in the 72 h prior to discovery of the remains, the DLE was defined as the date the remains were found minus 1 day. The DLE was defined as the date the remains were found minus 4 days, when the ME estimated that death had occurred between 72 h and 1 week prior to discovery. No estimate of the DLE was made when the ME estimated the age of the remains to exceed 1 week.

Results

In 2002 and 2003, there were 199 heat fatalities in Pima County, AZ. There were 183 cases classified as illegal immigrants on the basis of witnesses, accounts of family members, personal effects/documents, and other forensic evidence. There were 143 (72%) males. Age could be determined in only 144 (72%) cases. Among those cases, the average age was 34 ($S = 16$). The DLE could be determined in 138 (69%) of the cases.

Using the DLE, Figs. 1 and 2 plot the seasonal variation of heat fatalities in 2002 and 2003, respectively. The DAHT for each day of the year is also plotted as a reference point. It is clear from these figures that the majority of heat fatalities occurred at temperatures above 32°C . Table 1 illustrates the relationship by cross-tabulating the days in 2002 and 2003 on which the

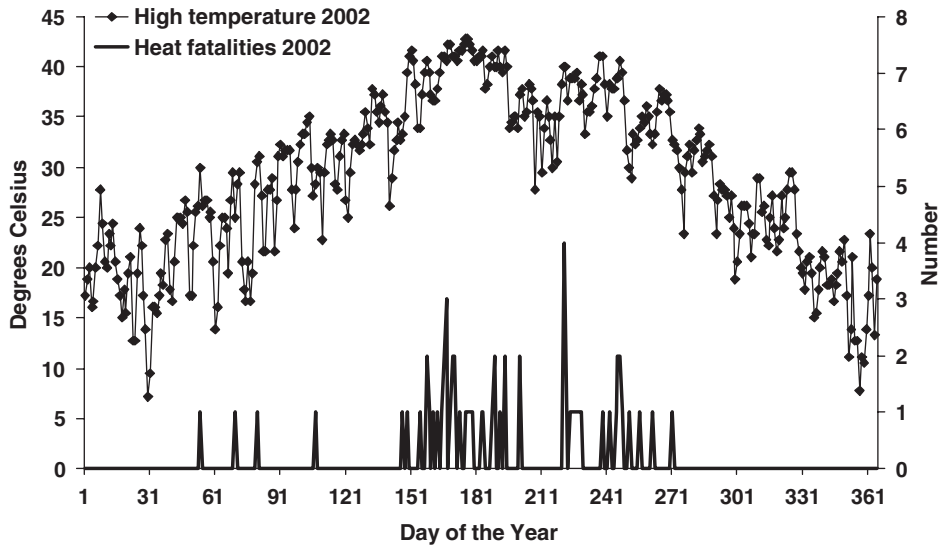


Fig. 1. Relationship of daily ambient high-temperature (DAHT) in 2002 to the number of heat fatalities for which a date of lethal heat exposure could be estimated.

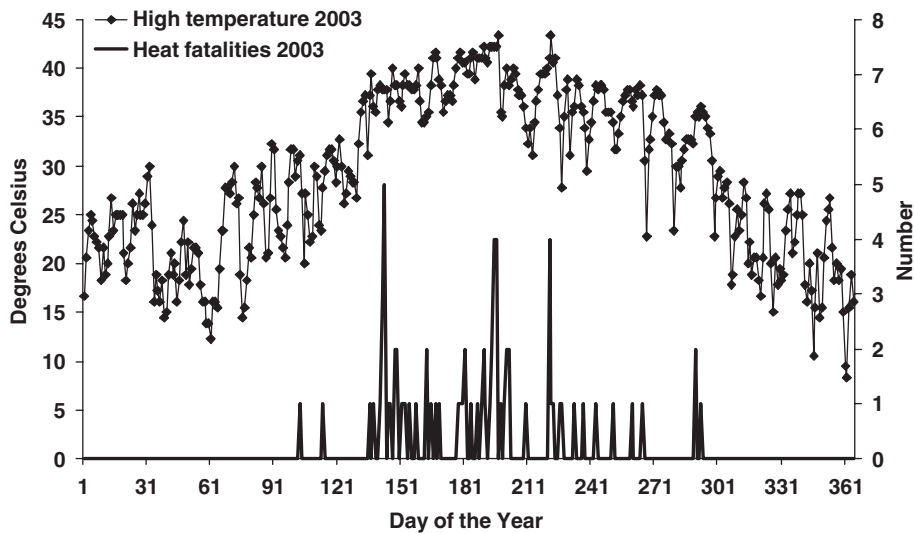


Fig. 2. Relationship of DAHT in 2003 to the number of heat fatalities for which a date of lethal heat exposure could be estimated.

temperature exceeded 32 °C, with the days on which one or more heat fatalities occurred. The odds ratio for this relationship is 21.05 (95% CI: 10.39–42.63). The odds of a heat fatality occurring on a day when the DAHT exceeds 32 °C was 21 times higher than the odds of a heat fatality occurring on a day when the DAHT did not exceed 32 °C.

The dose–response nature of the relationship can be described as the proportion of days at a specified DAHT on which one or more heat fatalities occurred. For example, the DAHT was 30 °C on 14 of the 730 days in

2002 and 2003. On 2 of those 14 days one or more heat fatalities occurred, a proportion of 0.14. Fig. 3 illustrates that as the DAHT increased, the proportion of days on which a heat fatality occurred increased. Logistic regression was used to analyze the relationship of DAHT (for each of the 730 days in 2002 and 2003) to the presence or absence of one or more heat fatalities on each day. For each degree of increase in temperature (°C), there was a 35% increase in the odds of one or more heat fatalities occurring ($\beta = 0.30$, Wald (1) = 83.23, $p < 0.001$, Exp (B) = 1.35).

Table 1

Relationship of ambient high temperatures $>32^{\circ}\text{C}$ and the occurrence of one or more heat fatalities in 2002 and 2003

		At least one heat fatality occurred on this day?	
		No	Yes
Ambient high temperature $>32^{\circ}\text{C}$ on this day?	No	430	9
	Yes	202	89

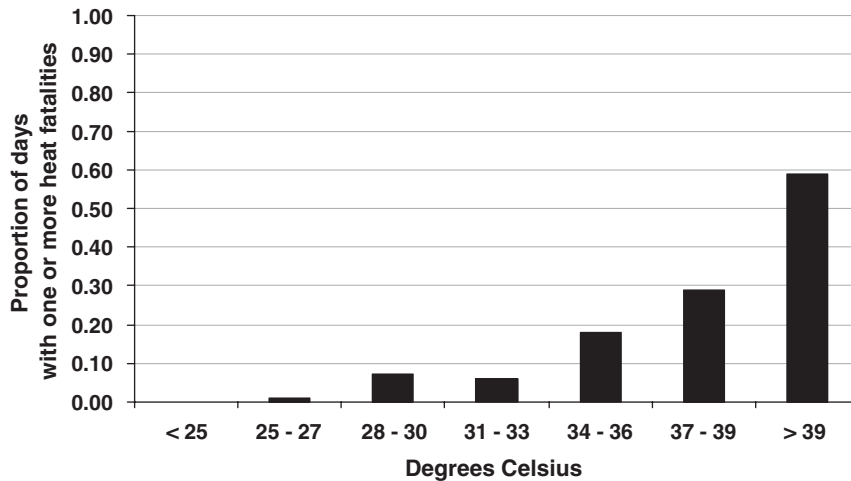


Fig. 3. Proportion of days in 2002 and 2003 ($N = 730$) with DAHT in the specified range on which one or more heat fatalities occurred.

Discussion

Our results support earlier studies which suggested that DAHTs above 32°C pose a high risk of fatal heatstroke for individuals who cannot engage in risk avoidance behaviors. Moreover, they expand upon the earlier studies by demonstrating the dose–response nature of the relationship between DAHT and the odds of a heat fatality occurring (Keatinge et al., 2000).

These results should not be interpreted in terms of the relative risk of death due to heat exposure. Because the majority of fatalities occurred among illegal immigrants, whose border crossing behaviors run the gamut from desperately ill-conceived to completely secure, and whose numbers cannot be credibly determined, it is impossible to know the number of persons at risk on any given day. Nor should these results be interpreted as indicating that high ambient temperatures are the primary factor in determining heat fatalities. Rather, these results indicate that high ambient temperatures systematically contribute to the risk of fatal heatstroke. They illustrate the danger of extended exposure to high ambient temperatures and provide information that can be used in weather and public health advisories (Bernard

and McGeehin, 2004). Future work should strive to further elucidate the key variables related to the deaths and to defining the population at risk.

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