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Identifying heat-related deaths by using medical examiner and vital statistics data: Surveillance analysis and descriptive epidemiology — Oklahoma, 1990–2011

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ABSTRACT

Objectives: Approximately 660 deaths occur annually in the United States associated with excess natural heat. A record heat wave in Oklahoma during 2011 generated increased interest concerning heat-related mortality among public health preparedness partners. We aimed to improve surveillance for heat-related mortality and better characterize heat-related deaths in Oklahoma during 1990–2011, and to enhance public health messaging during future heat emergencies.

Methods: Heat-related deaths were identified by querying vital statistics (VS) and medical examiner (ME) data during 1990–2011. Case inclusion criteria were developed by using heat-related *International Classification of Diseases* codes, cause-of-death nomenclature, and ME investigation narrative. We calculated sensitivity and predictive value positive (PVP) for heat-related mortality surveillance by using VS and ME data and performed a descriptive analysis.

Results: During the study period, 364 confirmed and probable heat-related deaths were identified when utilizing both data sets. ME reports had 87% sensitivity and 74% PVP; VS reports had 80% sensitivity and 52% PVP. Compared to Oklahoma's general population, decedents were disproportionately male (67% vs. 49%), aged $\geq$65 years (46% vs. 14%), and unmarried (78% vs. 47%). Higher rates of heat-related mortality were observed among Blacks. Of 95 decedents with available information, 91 (96%) did not use air conditioning.

Conclusions: Linking ME and VS data sources together and using narrative description for case classification allows for improved case ascertainment and surveillance data quality. Males, Blacks, persons aged $\geq$65 years, unmarried persons, and those without air conditioning carry a disproportionate burden of the heat-related deaths in Oklahoma.

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1. Introduction

A record heat wave in the southcentral United States during summer 2011 generated increased interest in heat-related mortality among public health officials in Oklahoma. The Centers for Disease Control and Prevention (CDC) estimates approximately 660 deaths occur annually in the United States directly associated with excess natural heat (CDC, 2013). This figure is likely a substantial underestimate of the actual number of deaths as no widely accepted consensus exists regarding specific criteria for defining heat-related mortality, deaths from other causes known to be exacerbated by heat (e.g., cardiovascular disease) might not be classified as heat related, and a medical examiner (ME) might not consider heat as a cause or contributor of death during non-heat wave periods (Basu and Samet, 2002; Ostro et al., 2009). Estimates of 22,000 – 45,000 heat-related deaths across Europe associated with a two week heat wave during August 2003 underscore the effects of excessive heat on human health (Basara et al., 2010; Patz

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et al., 2005).

Among the most vulnerable populations to heat-related illness are older adults and infants, persons with cardiovascular and psychiatric disease, bedbound persons, and those with lower socioeconomic status; the strongest protective factor is having a working air conditioner in the home (Basu, 2009; Bouchama et al., 2007; Naughton et al., 2002; Semenza et al., 1996). If heat preparedness partners target precautionary interventions to susceptible populations and behaviors, heat-related morbidity and mortality can be reduced among those at greatest risk. Climate model projections of hotter, longer, and more frequent heat waves indicate greater scrutiny is needed regarding this problem (Davis et al., 2003) Heat-related illness and death are preventable, and simple steps can save lives during hot summer months (CDC, 2005).

In Oklahoma, where the climate ranges from humid subtropical in the east to semiarid in the west (Oklahoma Climatological Survey, 2016), the Office of the Chief Medical Examiner (OCME) is responsible for investigating all sudden, violent, unexpected, unattended, and suspicious deaths, including heat-related deaths. The OCME works with law enforcement officials to conduct a medicolegal investigation of circumstances concerning the death, and the ME completes sections of the death certificate that indicate the cause, manner, and circumstances of death. Thus only a small fraction of all deaths are evaluated by the OCME. Therefore most death certificates are either completed by clinicians in the hospital or funeral directors and are forwarded to the vital statistics (VS) division of the Oklahoma State Department of Health (OSDH), where trained personnel enter the cause and manner of death into a VS database (Oklahoma State Department of Health, 2016). The cause of death is later coded according to the *International Classification of Diseases, Tenth Revision* (ICD-10) by using nosology software (WHO, 2007).

Heat-related mortality literature often relies on ICD codes to identify heat-related deaths, which likely underestimates the actual burden of disease. However, to better understand the true scope of heat-related mortality in Oklahoma, we employed a novel approach wherein we reviewed ME data along with VS data to identify heat-related deaths. Narrative descriptions in ME records were used for both case finding and case confirmation. Using ME narratives identified additional cases not found by using ICD codes alone and also served as the ultimate standard by which the sensitivity and specificity of our data sources were measured, providing additional confidence in the accuracy of our cases meeting the case definition.

In this study, all heat-related deaths in Oklahoma during 1990–2011 identified by using Oklahoma's ME database and VS records were compiled and reviewed. Specific heat-related ICD codes, cause-of-death nomenclature, or narrative description of the circumstances concerning death were reviewed to determine case inclusion and yield a more thorough approximation of heat-related deaths. To our knowledge, the OCME has used a consistent reporting practice for heat-related mortality during the study period. A comparison of the sensitivity and predictive value positive (PVP) for identifying heat-related mortality cases by using ME or VS data alone was performed. A descriptive epidemiologic analysis was also performed of heat-related mortality in Oklahoma, a region whose population is hypothesized to be more acclimatized to higher temperatures and thus at lower risk for heat-related mortality as evidenced by Anderson and Bell's (2009) demonstration that Oklahoma cities are in the bottom 20% of cities nationwide ranked by heat impact on all-cause mortality. Results of this study will be used to guide public health messaging and early warning heat advisories from OSDH and other heat preparedness partners during future heat waves. A similar epidemiologic evaluation and prevention strategy might be considered in regions of the world with comparable risk for heat-related morbidity and mortality.

2. Materials and methods

According to the National Association of Medical Examiners, a heat-related death is a death in which exposure to high ambient temperature either caused the death or was a substantial contributor. Heat-related death is based on a history of exposure to high ambient temperature and the reasonable exclusion of other causes of hyperthermia. The diagnosis can be established from circumstances concerning the death, investigative reports concerning environmental temperatures, or a measured antemortem body temperature at the time of collapse ($\geq 105^{\circ}$F or lower if cooling was attempted before arrival at the hospital or a clinical history of mental status changes and elevated liver or muscle enzymes is noted) (Donoghue et al., 1997).

Heat-related deaths were identified and classified by using a tiered strategy on the basis of specific heat-related ICD codes, cause-of-death nomenclature, and the narrative description of circumstances concerning the death gathered from VS and ME databases. VS data include ICD codes and cause-of-death nomenclature; ME data include cause-of-death nomenclature and a narrative description of the circumstances concerning death from scene investigation reports or final autopsy reports. For certain cases, ME data were unavailable or only partial ME data were available without a final autopsy report.

Queries of VS data for specific heat-related *International Classification of Diseases, Ninth Revision* (ICD-9) and ICD-10 codes during 1990–2011 in Oklahoma were performed; the ICD-9 coding scheme changed to ICD-10 in 1999 (WHO, 2007). Non-specific heat-related ICD codes such as “fever of other and unknown origin” (ICD-10 R50), in addition to environmental heat-specific heat-related ICD codes such as “exposure to excessive natural heat” (ICD-10×30), were included to ensure broad case ascertainment (Supplemental Material, Table S1). Heat-specific ICD codes did not have to be the primary ICD codes relating to the cause of death; codes could be in any position in the VS database for inclusion in the study. VS and ME data were also queried for specific heat-related cause-of-death nomenclature, namely *heat*, *hot*, *hyperthermia*, and *sun*.

After generating a list of all potential heat-related deaths from the ME and VS databases, the narrative description of the circumstances concerning death was used to classify cases as confirmed, probable, or not a case. Confirmed cases had a narrative description that was compelling for a heat-related death, along with heat-related ICD codes or cause-of-death nomenclature. Probable cases included *(a)* a narrative description that was compelling for a heat-related death but did not have any heat-related ICD codes or cause-of-death nomenclature or *(b)* a narrative description that was unclear, but a heat-related ICD code or cause-of-death nomenclature was present.

In addition, if ME data were unavailable for confirmation, two inclusion criteria were required to be considered a probable heat-related death. First, the death must have occurred during the warmer months of May–September. Second, environmental heat-specific heat-related ICD codes had to be present. Cases with a narrative description that was not compelling for a heat-related death or a narrative description that was unclear without any heat-related ICD codes or cause-of-death nomenclature were excluded. Case classification was reviewed and validated by OSDH public health officials. Complete case classification criteria are included in the text box.

Classification criteria for confirmed, probable, and non-cases of heat-related death in Oklahoma, 1990–2011.