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Heat Death Associations with the built environment, social vulnerability and their interactions with rising temperature

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ABSTRACT

In an extreme heat event, people can go to air-conditioned public facilities if residential air-conditioning is not available. Residences that heat slowly may also mitigate health effects, particularly in neighborhoods with social vulnerability. We explored the contributions of social vulnerability and these infrastructures to heat mortality in Maricopa County and whether these relationships are sensitive to temperature. Using Poisson regression modeling with heat-related mortality as the outcome, we assessed the interaction of increasing temperature with social vulnerability, access to publicly available air conditioned space, home air conditioning and the thermal properties of residences. As temperatures increase, mortality from heat-related illness increases less in census tracts with more publicly accessible cooled spaces. Mortality from all internal causes of death did not have this association. Building thermal protection was not associated with mortality. Social vulnerability was still associated with mortality after adjusting for the infrastructure variables. To reduce heat-related mortality, the use of public cooled spaces might be expanded to target the most vulnerable.

1. Introduction

In the face of climate change and more frequent and severe extreme heat events, it has become more important to understand which neighborhoods and populations are at risk of death from extreme heat and how properties of the urban environment contribute to or mitigate the risk of heat related death (United Nations, 2014). Heat related deaths can be prevented if individuals can cool themselves. Air conditioning is the most important form of cooling available in most cities and its absence from homes is a factor in heat mortality and morbidity (Blum et al., 1998; Semenza et al., 1996). In its absence, the U.S. Centers for Disease Control and Prevention recommend people "reduce their risk for heat-related illness by spending time in public facilities that are air-conditioned", specifically suggesting shopping malls and public libraries as public venues for accessing cooled space (U.S. Centers for Disease Control and Prevention, 2015). Local public health departments and emergency managers open and provide access to air-conditioned, cooling shelters in extreme heat events, as this is commonly believed to be helpful in reducing heat-related deaths, and neighbors are asked to check on elderly neighbors (Mees, 2015). There is indirect evidence that heat-health warning systems which couple early warnings with a broad array of emergency response measures save lives, though it is unknown which of the measures contribute to any reduction (Ebi et al., 2003).

A community's vulnerability to extreme heat can be understood as a function of its heat exposure, population characteristics and adaptive capacity. Exposure, in the form of increasing temperature, is related to mortality: in one study for every 10 °F increase in ambient temperature, there was a 2.6% increase in cardiovascular mortality (Basu, 2009). The temperature-mortality relationship may be non-linear so that longer duration heat events

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may have more population effects (Anderson and Bell, 2011). Population characteristics including socio-economic and health factors contribute to heat-mortality relationships. Age is commonly cited as a risk factor with some studies finding that populations are at higher risk of mortality as well as persons under age five (Luber and McGeehin, 2008). Minority groups are frequently at greater risk of heat mortality too, though studies are not consistent in this finding (Hondula et al., 2012; Uejio et al., 2011; Golden et al., 2008). Poverty, chronic health conditions and social isolation can be risk factors (Harlan et al., 2013; Kovats and Hajat, 2008, McGeehin and Mirabelli, 2001, Le Tertre et al., 2006; Klinenberg, 2002). Which populations are at risk varies between and within cities likely due to differences in environment, climate, culture, demography and adaptations (Harlan et al., 2013; Reid et al., 2012; Hondula et al., 2015; Davis et al., 2003b).

Less well studied are adaptations to the effects of climate change that might reduce heat wave mortality. Adaptation is "adjustment in natural or human systems in response to actual or expected stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Huang et al., 2011; Hess et al., 2012). Adaptive capacity refers to the resources available for adaptation and the ability to use them effectively and efficiently. These resources can come in many forms including social, educational, physical or financial and together form the inputs for adaptation interventions, programs and community actions (White-Newsome et al., 2014; Huang et al., 2011). Access to cooled space may be the most important physical resource imparting adaptive capacity and reducing the risk of heat-related health effects (Harlan et al., 2013; Reid et al., 2012; Ostro et al., 2010; O'neill et al., 2005b). It can come from several sources including air-conditioning at work and home and from publicly accessible cooled spaces such as libraries, commercial venues and public transportation. But simply getting more people to use home air-conditioning is not a panacea as estimates of increasing heat and water shortages may strain the electricity grid's ability to provide power during extreme heat events (Sathaye et al., 2012). Buildings with thermal properties that allow it to heat slower in the sun and maintain cool air within may, besides contributing to environmental sustainability and reducing strain on the power grid, provide further adaptive capacity in the face of extreme heat. Similar to social vulnerability, adaptive capacities and their potential for reducing mortality could vary between regions. For instance, cooling centers that are integrated into a community may be more broadly useful in an extreme heat event than cooling centers that carry the stigma attached to primarily serving the homeless or senior population (Hayden et al., 2011; White-Newsome et al., 2014).

This study focuses on the relationship between social vulnerability and adaptive capacity in Maricopa County, Arizona. Maricopa County includes Phoenix, the second most populous city in the southwestern United States (Los Angeles is the most populous), where summertime temperatures frequently exceed 105 (40.5 °C) F, as well as Mesa, Glendale, Chandler, Scottsdale and Tempe. The daily mean summer temperature in Phoenix, 33 °C (91.4 F), is the highest of all major metropolitan areas in the United States (Petitti et al., 2016). Several studies have addressed aspects of adaptive capacity in Phoenix and Maricopa. One study of three socioeconomically vulnerable Phoenix neighborhoods at potential high risk from extreme heat found access to cooled space was more nuanced than simply having an air conditioner in the home (Hayden et al., 2011). The cost of electricity prevented over 36% of survey respondents from using their air conditioner and an additional 6% reported having a nonfunctional air conditioner. 38% of participants endorsed feeling too hot inside their homes and home renters and Hispanic respondents were significantly more likely to experience this. The authors observed that air conditioner use was "often limited to simply reducing the extreme heat but not necessarily providing relief" [p275]. Hydration and cooling centers were not well used by this sample: Only 9 of 359 respondents had ever used a heat refuge station. Other Phoenix-based surveys, and multi-city studies report that residential air-conditioning may be installed but residents may not turn them on due to the costs of electricity or disliking the feel (Sheridan, 2007; Lane et al., 2014).

Thus, while characteristics of the urban infrastructure such as the availability of residential air conditioners can contribute to heat's impact on health it is necessary to examine other sources of adaptation such as building thermal properties that maintain cool air and retard heating and access to public air-conditioned spaces where one may cool down. For instance, residents living in communities with air-conditioned spaces and buildings that heat slowly might experience less risk as temperatures increase than residents without these protections. Though the thermal properties of buildings, which in this context means the ability of buildings to keep the indoor space cool, has also been offered as a factor in heat mortality we know of little research that has tested this connection (Kovats and Hajat, 2008; Mavrogianni et al., 2012; Anderson et al., 2013). Similarly, individuals cope with extreme heat in a variety of ways. Kalkstein and Sheridan reported that 72% of respondents in their Phoenix survey "went to an air-conditioned location or stayed indoors" on excessively hot days (Kalkstein and Sheridan, 2007). This suggests that one way individuals may cope is by going to publicly available cooled spaces, though the compound nature of their survey question limits any estimation of frequency. On the one hand, the senior centers, libraries, community centers and other community sites that are designated as cooling centers may be distributed sparsely, unevenly and loosely tied to the neighborhoods most in need. Fraser reported that only 2% of Maricopa County, Arizona residents are within walking distance of an official cooling center (Fraser et al., 2016). On the other hand, individuals may seek non-residential, publicly available air conditioned spaces such as shopping malls and libraries. Still, we know of no research examining how differential access to air conditioned public spaces relates to health outcomes, a question we ask in this study. Examining the spatial variation of social vulnerability to heat, a common approach in heat-vulnerability studies, should examine these adaptive capacities that may mitigate vulnerability.

This paper explores the contributions of exposure, susceptibility and adaptive capacity to extreme heat mortality. Specifically, it investigates how susceptibility and adaptive capacity, operationalized as social vulnerability and infrastructure factors respectively, contribute to mortality from extreme heat and whether the relationships between mortality and the social vulnerability and infrastructure factors are sensitive to increasing temperature in Maricopa County, Arizona. The infrastructure factors examined are access to publicly available air conditioned space, home air conditioning and the thermal protective properties of residential buildings. We hypothesized that census tracts with increased social vulnerability, less home air conditioning, less access to publicly available cooled space and lower scores on an index of building thermal protection would have excess heat mortality.

2. Methods

Two outcomes were evaluated: mortality from all internal causes and mortality from heat-related illnesses. All internal causes of mortality is the most frequent overall mortality outcome studied because it is broad enough to capture the full range of causes of death from heat (excessive heat can exacerbate chronic medical conditions thereby leading to death), it provides sufficient power to detect associations and it allows comparison to a wider