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Intra-urban vulnerability to heat-related mortality in New York City, 1997–2006

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ABSTRACT

The health impacts of exposure to summertime heat are a significant problem in New York City (NYC) and for many cities and are expected to increase with a warming climate. Most studies on heat-related mortality have examined risk factors at the municipal or regional scale and may have missed the intra-urban variation of vulnerability that might inform prevention strategies. We evaluated whether place-based characteristics (socioeconomic/demographic and health factors, as well as the built and biophysical environment) may be associated with greater risk of heat-related mortality for seniors during heat events in NYC. As a measure of relative vulnerability to heat, we used the natural cause mortality rate ratio among those aged 65 and over (MRR_{65+}), comparing extremely hot days (maximum heat index 100 °F+) to all warm season days, across 1997–2006 for NYC's 59 Community Districts and 42 United Hospital Fund neighborhoods. Significant positive associations were found between the MRR_{65+} and neighborhood-level characteristics: poverty, poor housing conditions, lower rates of access to air-conditioning, impervious land cover, surface temperatures aggregated to the area-level, and seniors' hypertension. Percent Black/African American and household poverty were strong negative predictors of seniors' air conditioning access in multivariate regression analysis.

1. Introduction

The adverse health impacts of summertime heat are a significant problem in New York City (NYC) and many other cities around the world, and are expected to increase with a warming climate (Knowlton et al., 2007). Excessive exposure to high heat is associated with increased rates of heat stress, heat stroke, and premature death (O'Neill and Ebi, 2009). Heat-associated mortality typically presents as excess mortality due to cardiovascular or respiratory causes during hot weather (Hoshiko et al., 2010). As a result of extreme events such as the premature deaths of 14,800 people in France during the August 2003 heat wave (Observatoire régional de santé (ORS), 2003), awareness of heat-related mortality has increased. As cities create climate adaptation plans to protect vulnerable populations, understanding the causes of intra-urban spatial heterogeneity of these premature deaths should help identify locations and population groups at greatest risk while informing the search for modifiable exposures.

A number of studies have identified individual risk factors for vulnerability to heat waves. Those over 65 years of age and people with pre-existing cardiovascular and/or respiratory illnesses are especially vulnerable populations (Basu and Samet, 2002). Vulnerable populations also include young children, the obese, and those using medications that impede thermoregulation (New York City Department of Health and Mental Hygiene (NYCDOHMH), 2012).

There is also a growing understanding of the role of place in creating increased risk for heat-associated mortality. Analysis of mortality data in France indicates that deaths during the 2003 heat wave were disproportionately concentrated in poorer neighborhoods with higher levels of immigrants and substandard

Abbreviations: CD, community district; heat wave, three or more consecutive days of equal to or greater than 90°F maximum temperatures; HI, the heat index (HI), or apparent temperature: a measure that combines relative humidity and ambient temperature (Steadman, 1979); MRR_{65+}, mortality rate ratio of persons aged 65 and older; UHF, United Hospital Fund; UHI, urban heat island

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housing (Observatoire régional de santé (ORS), 2003). People at elevated risk of mortality during a Chicago heat wave in 1995, which led to more than 700 excess deaths, included the elderly, the poor, those with limited mobility and little social contact, and those with pre-existing medical or psychiatric conditions, as well as those with place-based risk factors such as poor access to public transportation or air-conditioned neighborhood places (Klinenberg, 2002; O'Neill and Ebi, 2009; Semenza et al., 1996). Risk of mortality in that event was higher in the Black community; for people living in certain types of low income and multi-tenant housing, such as single-room occupancy apartment buildings; and for those living on the top floors of buildings (Klinenberg, 2002; Semenza et al., 1996). Access to and use of home air conditioning was protective against heat-related death and risk of heat stroke in four U.S. cities (O'Neill et al., 2005; Semenza et al., 1996). Black residents of these cities had one-half the access to home air conditioning as other racial/ethnic groups, and a higher risk of heat-mortality (O'Neill et al., 2005).

In New York, as in other cities, summertime heat can lead to elevated mortality and morbidity rates, especially during the extended periods of hot weather (Basu and Samet, 2002; Braga et al., 2002; Ellis et al., 1975; Kalkstein and Greene, 1997; Marmor, 1975; McGeehin and Mirabelli, 2001). In NYC, the effects of temperature on mortality were observable above a threshold temperature range, with a minimum mortality temperature of approximately 66.4 °F (Curriero et al., 2002; O'Neill and Ebi, 2009). In a study of the daily variation in warm season natural-cause mortality for 1997–2006 in New York City, Metzger et al. (2010) found that the same-day maximum heat index (HI) was linearly related to mortality risk across its range. Heat waves in July and August 2006 in NYC were associated with 46 confirmed heat stroke deaths within the city, with a greater proportion in Queens neighborhoods (New York City Department of Health and Mental Hygiene (NYCDOHMH), 2006). Additionally, approximately 100 excess deaths occurred during the July 27-August 5, 2006 heat wave, an 8% increase over the average daily death rate (New York City Department of Health and Mental Hygiene (NYCDOHMH), 2006). Chronic diseases such as cardiovascular disease, mental health disorders and obesity were common comorbidities in heat illness and deaths in NYC between 2000 and 2011 (Centers for Disease Control and Prevention (CDC), 2013). Among hyperthermia deaths with information available, none of the deceased had used a working air conditioner (Ibid.). "Rates of heat illness and death increased with age, were typically higher among males than females for those aged <65 years, and increased with neighborhood poverty" and the homeless were at greater risk for heat-related mortality and illness (Centers for Disease Control and Prevention (CDC), 2013, p. 618).

These health effects could worsen during the 21st century due to a changing climate. Temperature projections for the NYC metropolitan region using a global-to-regional climate modeling system and two greenhouse gas emissions scenarios, A2 and B2, yielded a mean increase of 70% in heat-related mortality rates by the 2050s within the region compared to the 1990s (Knowlton et al., 2007). A net increase in annual temperature-related deaths of 15.5–31% was estimated for Manhattan, New York, in the 2080s as compared with the 1980s, as increases in heat-related mortality outweighed reductions in cold-related mortality using the B1 and A2 emissions scenarios and 16 downscaled global climate models (Li et al., 2013).

Research suggests that the physical and social characteristics of neighborhoods are important for understanding the spatial and social distribution and variability of heat-related mortality within cities (Clarke, 1972; Harlan et al., 2006, 2013; Klinenberg, 2002; Smoyer, 1998). The urban heat island effect, which leads to higher surface and near-surface air temperatures in dense urban areas than surrounding suburban and rural areas, may increase the health effects of summer temperatures, as micro-urban temperature variation and elevated nighttime temperatures increase exposure to heat for those without air conditioning and increase the risk of heat-related disease and mortality (Patz et al., 2005; Smargiassi et al., 2009; Uejio et al., 2011).

Heat island intensity is spatially heterogeneous in urban landscapes, so that some areas may be significantly cooler than others during a heat wave (Harlan et al., 2006; Smoyer, 1998). The thermal environment (microclimates) within cities varies because of physical layout and urban design, land use mix, and vegetative cover and street trees (Hart and Sailor, 2008; Slosberg et al., 2006). Hart and Sailor (2008) found that roadway area density was an important determinant of local heat island magnitudes for Portland, Oregon, while the main factor distinguishing warmer from cooler areas in the Portland metropolitan region was tree canopy cover. Using thermal infrared data derived from Landsat imagery, Slosberg et al. (2006) found that spatial variability in NYC's surface temperatures was most associated with changes in albedo and a measure of vegetation coverage, the Normalized Difference Vegetation Index (NDVI). The association between the thermal environment of neighborhoods and demographic risk factors for heat-related health effects was found to be significant in the city of Phoenix, where "lower socioeconomic and ethnic minority groups were more likely to live in warmer neighborhoods with greater exposure to heat stress" (Harlan et al., 2006). Jesdale et al. (2013) found that non-Hispanic Blacks, non-Hispanic Asians and Hispanics were more likely than non-Hispanic Whites to live in block groups with heat risk-related land cover (HRRLC), where at least half the population "experienced the absence of tree canopy and at least half of the ground was covered by impervious surface" (p. 811).

Although temperature varies within cities in ways relevant for heat exposures, little is known in NYC about how this affects health outcomes. Because this knowledge may suggest possible interventions to reduce heat-associated health problems, we examined the relationship between characteristics described at the neighborhood scale, including biophysical, demographic and population health characteristics, and heat-related mortality rates within New York City.

1.1. Place and health

The conceptual basis for this research is located in the growing body of scholarship examining the influence of place-based characteristics and context on population health. For much of the post-World War II period, environmental health research focused on understanding the individual-level risk factors and their associated biological mechanisms that may lead to disease causation and disparities in mortality rates (Corburn et al., 2006; Diez Roux, 2001; Schwartz, 1994). More recently, recognition of the effects of place as a determinant of the distribution of health outcomes has increased. Researchers from medicine, epidemiology and the social sciences are increasingly interested in understanding the cumulative effects of the spatial clustering of physical and psychosocial hazards often experienced in low-income neighborhoods and communities of color (Bullard, 1990; Corburn et al., 2006; Northridge et al., 2003).

The impacts of neighborhood conditions on population health are important and should be analyzed to target climate adaptation strategies (Rosenthal et al., 2007). Health researchers have theorized that neighborhood conditions and characteristics may exert an effect on health through influence on behaviors, such as risk-taking and levels of physical activity, or by acting to modify the influence of environmental exposures on individual-level health, through impacts on individual stress and the immune system