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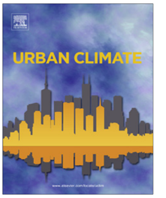

Heat mortality in Berlin – Spatial variability at the neighborhood scale

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Heat stress increasingly affects urban populations in higher geographical latitudes. Related adverse health effects are expected to increase due to urbanization, population aging, and global warming. While many studies have examined the relationship between heat and mortality, only a few have examined the intra-urban spatial variability between them. This missing research is particularly evident for northern mid-latitude cities, where populations are not prepared for heat stress. The aim of this study is therefore to investigate heat-related excess mortality in its spatial variability at the neighborhood scale (397 planning areas) for Berlin, the capital of Germany. We analyzed age-standardized mortality rates by calculating the relative heat mortality risk ratio for months with and without severe heat waves. Local indicators of spatial association were used to locate spatial clusters. The results highlighted the intra-urban variability of heat-related excess mortality, and demonstrated clustering for the planning areas of Berlin. Temporal aggregation of mortality data enabled a neighborhood-scale analysis. Resulting heat-related excess mortality maps allow urban decision makers to identify hot spots for emergency and adaptation planning, and serve as a basis for further investigations of heat stress risk on an individual level.

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1. Introduction

Statistical evidence for the association of increased mortality and extreme temperature in urban areas has been globally documented (Oudin Åström et al., 2011). The risk of suffering from adverse human health impacts due to heat is expected to increase, particularly in urban areas located in the temperate climate zone (Hansen et al., 2008). Researchers have established that increasing rates of urbanization, demographic and climatic change are the major driving forces affecting the likelihood of adverse health effects due to heat in populations that are not adapted to severe heat impacts (Sheridan and Dolney, 2003). Research must therefore explore and assess the vulnerability of urban populations in order to provide knowledge to support emergency response and preventive adaptation planning (Turner et al., 2003; Harlan et al., 2006; Cutter and Finch, 2008; Leichenko and Solecki, 2013).

Extreme heat has direct and indirect negative effects on human health. It compromises the physiological thermoregulation process and may directly lead to dizziness or fainting (Havenith, 2001). Heat may even lead to death due to acute heart failure or stroke and because it exacerbates many negative pre-existing health conditions (Nixdorf-Miller et al., 2006; Hattis et al., 2012). Many studies have found statistical correlations between heat and increased mortality, independent of the cause of death (‘‘all-cause mortality’’). To estimate the proportion of mortality in a population that can be attributed to heat, heat-related excess mortality rates can be calculated as relative risk by dividing the expected (baseline) mortality from the observed mortality during a specific heat event (Ishigami et al., 2008; Gosling et al., 2009; Oudin Åström et al., 2011; Scherer et al., 2013; Xu et al., 2013). Since heat-related deaths may be attributed to many different causes, most heat mortality studies have used all-cause mortality as a measure (Yu et al., 2010; Oudin Åström et al., 2011; Hondula et al., 2012; Xu et al., 2013). Several studies reported mortality due to cardiovascular and respiratory diseases to be associated with heat exposure (Ishigami et al., 2008; Chan et al., 2010; Oudin Åström et al., 2011; Basu and Malig, 2011). However, heat exposure itself is generally not classified as a direct cause of death, and underlying risk factors remain largely unclear. Therefore, the spatial patterns of an urban populations’ multidimensional vulnerability to extreme heat is a current research gap worth investigation (Hattis et al., 2012; Johnson et al., 2012; Harlan et al., 2013; Hondula et al., 2013).

Previous research has found clear temporal heat mortality effects on an aggregated spatial level for large metropolitan areas (O’Neill et al., 2003; Gosling et al., 2009; D’Ippoliti et al., 2010). Using daily mortality data, researchers found no evidence for temporal mortality displacements of more than a few days, if at all (Basu and Malig, 2011; Oudin Åström et al., 2011; Hattis et al., 2012). In general, epidemiologic research identified elderly and those suffering from chronic diseases as the most vulnerable. Most studies used a 65-year threshold and found increasing death rates for the elderly, in particular for respiratory and cardiovascular mortality, during heat events (Chan et al., 2001; Oudin Åström et al., 2011). However, other studies did not find a statistical relationship (O’Neill et al., 2003; Xu et al., 2013). Robine et al. (2012) argued that the statistical effect of increased mortality among the elderly might be distorted by the premature death of the weakest, leading to more robust older populations. Most studies about heat effects on mortality are challenged by constraints in the detail level of the available mortality data. Census or death certificate data contain differing characteristics regarding time and place of death, and countries’ data protection policies limit the amount of additional information (age, causes, pre-conditions) available (e.g., Harlan et al., 2006; Xu et al., 2013).

Heat mortality mapping allows the exploration of spatial variations of heat stress risk (Borden and Cutter, 2008; Oudin Åström et al., 2011; Harlan et al., 2013). Heat stress risk (e.g., heat mortality) is a function of hazard and vulnerability, where the external heat impact represents the hazard, and vulnerability is determined as function of a population’s heat exposure (influenced for example by urban green, the built structure and density), heat sensitivity (determined by individual physiology), and adaptation capacity (education and income) towards heat within a city (Scherer et al., 2013). Accordingly, vulnerability varies among individuals, and therefore over intra-urban spatial units or subpopulations (Harlan et al., 2013). In general, mapping heat mortality within metropolitan areas is needed at the finest spatial scale possible, both as a prerequisite for emergency resource allocation and preventive adaptation planning, and to investigate potential risk factors (Johnson et al., 2012; Hondula et al., 2012; Harlan et al., 2013). Regarding the spatial resolution of the analysis unit,