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Review

Effect modification of individual- and regional-scale characteristics on heat wave-related mortality rates between 2009 and 2012 in Seoul, South Korea

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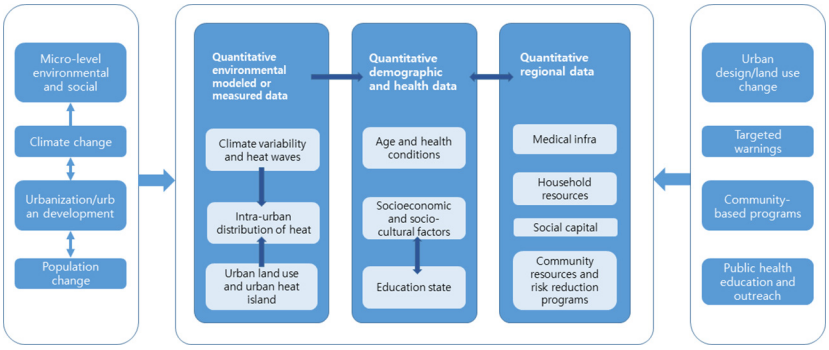
HIGHLIGHTS

- We studied heat wave mortality rates in Seoul between 2009 and 2012.
- Potential individual- and district-scale causative factors were investigated.
- Effect size of heat wave on mortality increased according to individual factors and regional level on heat wave day.
- More vulnerable individuals had low levels of education.
- Districts with higher mortality rates had less green space and fewer hospitals.

GRAPHICAL ABSTRACT



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ABSTRACT

Many studies have investigated the associations between heat waves, ambient temperature, cold spells, and mortality or morbidity. Some studies have utilized effect modification to reveal the factors that increase an individual's susceptibility to temperature extremes, which can then be used to reshape public policy. In this study, we used a time-stratified case-crossover technique to examine how individual- and regional-scale characteristics modified heat wave-related impacts on mortality rates in Seoul, South Korea, between 2009 and 2012. We defined a heat wave as having at least two consecutive days with a daily mean temperature greater than or equal to the 95th percentile recorded in each of Seoul's twenty-five districts. At the individual scale, citizens classified as belonging to a lower education group had a higher vulnerability to heat wave-related morbidity or mortality [odds ratio (OR) 1.261; 95% confidence interval (CI): 1.034–1.538]. At a regional scale, death during heat waves was more likely to occur in districts with a high deprivation index (OR = 1.194; 95% CI: 1.028–1.388). And a low proportion of green space around buildings (OR = 1.178; 95% CI: 1.016–1.366), a low proportion of rooftop green space (OR = 1.207; 95% CI: 1.042–1.399), or those that had fewer hospitals (OR = 1.186; 95% CI: 1.019–1.379). Our data show that mortality during heat waves is more likely where these individual and regional-scale vulnerabilities overlap. Our findings support evidence of mortality impacts from heat waves and provide a basis for selection to policy makers choose on the target groups to reduce the public health burden of heat waves.

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Contents

1. Introduction

The weather variability is a risk factor for mortality and many studies have been carried out in order to reveal the relationship between mortality and environmental variables, especially air temperature (Huynen et al., 2001; Curriero et al., 2002; Chung et al., 2009; Gasparrini et al., 2015). In addition, studies on the association between heat waves and health have been carried out with consideration of effect modifications as well as overall environmental factors such as weather and air pollution.

Many investigations into the links between heat waves and mortality rates have utilized effect modification (O'Neill et al., 2003; Goggins et al., 2012, and Ma et al., 2015) to study spatial variations and regional- to local-scale factors (Vaneckova et al., 2010; Yardley et al., 2011, and Hondula and Barnett, 2014). However, individual level characteristics other than these spatial variations and regional-to local-scale characteristics are also known to have a commanding influence on a person's health. It has long been known that heat waves increase the risk of mortality and morbidity, and the most vulnerable groups within any given population have been highlighted by several seminal studies. Previous works have suggested that the elderly, females, and/or people with chronic health problems are at the highest risk in all countries studied (O'Neill et al., 2003; Schwartz, 2005, and Chan et al., 2012). Although these characteristics are typically associated with high mortality rates, their severities of the mortality rates are expected to fluctuate over time according to meteorological conditions. Since factors such as age, gender, social status, and education level have no such climatic association, they are ideal for investigating whether they act as potential effect modifiers or not.

Many previous studies have investigated both the impact of heat waves on mortality, and the association between temperature and mortality rates in major cities in South Korea (Kim et al., 2006; Son et al., 2012). Heat waves in these studies have been defined differently in terms of their temperatures and durations, and these results are thus not directly comparable between different cities. In a previous study, one heat wave definition was applied to the 25 districts of Seoul and the association between heat waves and mortality at the individual level were examined. In this study, however, we investigated effect modification on heat wave days in Seoul at individual and regional levels based on the daily average temperature observed by 25 administrative districts. To our knowledge, there has been a lack of previous study into effect modification at the individual (i.e., personal) and regional scale. Our investigation took into account not only the individual level and the municipal administrative district, but also comprehensively evaluated the overall characteristics of the area at the local level. We estimated the effects that heat waves have on mortality in Seoul, South Korea, from 2009 to 2012, and evaluated effect modifications at the individual and regional scale in order to understanding their impacts. Our study focused on this urban area in order to allow comparisons of our results with (1) the reported effects of regional-scale characteristics, and (2) data reported for heat-related mortality rates within urban areas with similar characteristics.

The purpose of this study is to compare regional characteristics rather than conduct direct comparison by specific regions. In other words, we aim to compare the results of the study with the characteristics of the region and our results conducted in Seoul.

2. Material and methods

2.1. Study area and mortality data

The metropolitan area of Seoul—the capital of South Korea—had a total area of 605.21 km^2 in 2014, and a population of 9,631,482 in 2010 (identified via census data). Mortality data showing cause of death, age at the time of death, gender, marital status, employment type, and education level were obtained for twenty-five districts of Seoul from the Korea Bureau of Statistics. These data excluded those for accidental mortality, determined according to definitions provided by the International Classification of Disease (10th edition; ICD-10 codes A00-R99). In addition, we only considered deaths in Seoul that occurred during the warm season each year from 2009 to 2012, defined herein as the period between June 1 and August 31.

2.2. Environmental data

Daily weather data were obtained for each district from the Seoul Metropolitan Government records, which were based on data measured by the Korea Meteorological Administration. Meteorological data are observations of the Automatic Weather Station (AWS) provided by the Korea Meteorological Administration, which has one or more sites in each district. The data of observed weather conditions of 25 different districts were applied by matching the residence address of the deceased and the region where the observation equipment belongs. Air pollutant data for particulate matter <10 μm in aerodynamic diameter were obtained from the publically accessible Seoul air quality website (http://cleanair.seoul.go.kr/air_pollution.htm?method=average).

2.3. Effect modification

We categorized potential effect modifiers as those that operated at an individual (i.e., personal) or regional level. The former included gender, marital status, type of employment, and education status (obtained from mortality data), and the latter included economic status, environmental status, and the quality of medical infrastructure. We have investigated the integrated effects that a wide range of socio-economic (e.g., social status, income), demographic (e.g., gender, age),