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Temperature modifies the association between particulate air pollution and mortality: A multi-city study in South Korea ☆

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HIGHLIGHTS

- Effect modification of temperature on the air pollution-mortality was investigated.
- Cause-specific death, age and sex categories were explored.
- Strongest association was seen for the younger (age <65) or men during very hot days.
- Strongest association was seen for the older (age≥65) or women during hot days.
- Modification patterns were different by the cause of death, age and sex.

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ABSTRACT

Substantial epidemiologic literature has demonstrated the effects of air pollution and temperature on mortality. However, there is inconsistent evidence regarding the temperature modification effect on acute mortality due to air pollution. Herein, we investigated the effects of temperature on the relationship between air pollution and mortality due to non-accidental, cardiovascular, and respiratory death in seven cities in South Korea. We applied stratified time-series models to the data sets in order to examine whether the effects of particulate matter <10 μm (PM_{10}) on mortality were modified by temperature. The effect of PM_{10} on daily mortality was first quantified within different ranges of temperatures at each location using a time-series model, and then the estimates were pooled through a random-effects meta-analysis using the maximum likelihood method. From all the data sets, 828,787 non-accidental deaths were registered from 2000–2009. The highest overall risk between PM_{10} and non-accidental or cardiovascular mortality was observed on extremely hot days (daily mean temperature: >99th percentile) in individuals aged <65 years. In those aged ≥65 years, the highest overall risk between PM_{10} and non-accidental or cardiovascular mortality was observed on very hot days and not on extremely hot days (daily mean temperature: 95–99th percentile). There were strong harmful effects from PM_{10} on non-accidental mortality with the highest temperature range (>99th percentile) in men, with a very high temperature range (95–99th percentile) in women. Our findings showed that temperature can affect the relationship between the PM_{10} levels and cause-specific mortality. Moreover, the differences were apparent after considering the age and sex groups.

1. Introduction

Many epidemiologic studies have shown that ambient air pollution has adverse effects on mortality (Chen et al., 2004; Dockery et al., 1993; Mar et al., 2000; Samet et al., 2000; Wong et al., 2008). Temperature also has an effect on daily mortality (Curriero et al., 2002; McMichael et al., 2008), and a strong association between temperature and mortality has been detected with a generally nonlinear relationship of J-, U-, or V-shaped exposure responses in different countries (Baccini et al., 2008; Basu and Samet, 2002; Braga et al., 2001a; Guo et al., 2011).

Temperature is usually considered as a confounder in the study of air pollution. Therefore, when estimating the unconfounded effects of air pollution on mortality, an adjustment for temperature is typically warranted. However, the interactions between temperature and air pollution have received less attention.

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Temperature may act as an effect modifier, but this idea remains controversial (Hales et al., 2000; Katsouyanni et al., 1993; Roberts, 2004; Samet et al., 1998). However, in several recent studies, a significant interaction was detected (Park et al., 2011; Qian et al., 2008; Ren and Tong, 2006; Stafoggia et al., 2008). Season-specific approaches have also shown that the adverse effects of air pollution are more apparent in the warm season, although substantial variations have been observed across locations (Nawrot et al., 2007; Peng et al., 2005).

It is thought that air pollution affects certain subgroups of the population to a greater extent (WHO, 2004). According to consistent findings from many countries, vulnerability to the effects of air pollution may be affected by population demographic characteristics such as age and sex on the relationship between air pollution and daily mortality (Atkinson et al., 2001; Bateson and Schwartz, 2004; Cakmak et al., 2006; Gouveia and Fletcher, 2000; Kan et al., 2008; Katsouyanni et al., 2001). Additionally, people with pre-existing health problems such as cardiovascular and respiratory diseases seem to be more susceptible (Anderson et al., 2003; Basu, 2009; Bateson and Schwartz, 2004; Gasparrini et al., 2012; Goldberg et al., 2001; Katsouyanni et al., 2001).

In the present study, we investigated the modification effects of temperature on the relationship between air pollution and the different causes of mortality in seven cities in South Korea. Moreover, we investigated the temperature modification effect on the PM–mortality relationship by age and sex.

2. Materials and methods

2.1. Scope of the study and data collection

From January 1, 2000 through December 31, 2009, the data set used in this study consisted of meteorological variables, air pollution, and daily information on health outcomes in seven metropolitan cities in South Korea: Seoul, Incheon, Busan, Daegu, Daejeon, Gwangju, and Ulsan (Fig. 1). The information on weather variables was obtained from the Korean Meteorological Office and included data on the daily mean temperature (°C), daily mean relative humidity (%), and daily mean pressure (hPa). For air pollution, we collected data on particulate matter < 10 μm (PM_{10}) in aerodynamic diameter from the Korean National Institute of Environmental Research. Concentrations of the air pollutants were measured every 15 min at 88 monitoring stations (Seoul: 27, Incheon: 11, Busan: 16, Daegu: 11, Daejeon: 6, Gwangju: 5, and Ulsan: 12) during the study period. We calculated the daily representative concentration value of PM_{10} for each metropolitan city by averaging the hourly values of all the monitoring stations per metropolitan city, which comprised 24-h average concentrations of PM_{10}.

Daily mortality counts were obtained from the Korea National Statistics Office of the seven cities. All the diseases were diagnosed on discharge and were classified according to the International Classification of Disease, version 10 (WHO, 1996). For analysis, we excluded mortality due to accidents and suicide; therefore, we only examined non-accidental mortality (codes A00–R99 for total non-accidental mortality,

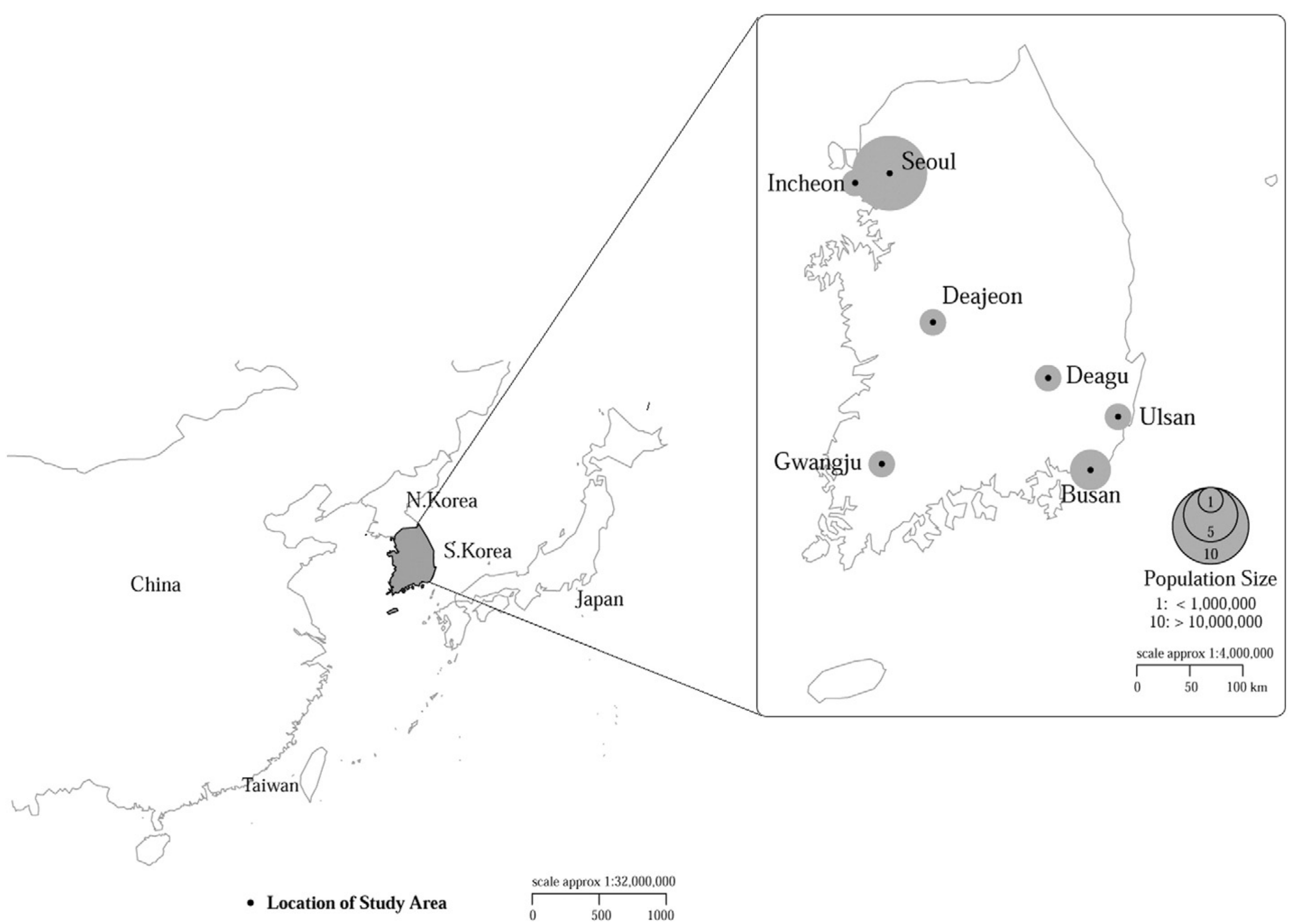

Fig. 1. Location of the seven South Korean cities.