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Temperature modifies the acute effect of particulate air pollution on mortality in eight Chinese cities

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HIGHLIGHTS

► Few studies examine the interaction between temperature and PM_{10} on mortality.
► Extremely high temperature intensified the effects of PM_{10} in 8 Chinese cities.
► Our study has implications for both air pollution and global climate change.
► This is the first multi-city study of its kind in Asian developing region.

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ABSTRACT

Background: Both temperature and particulate air pollution are associated with increased death risk. However, whether the effect of particulate air pollution on mortality is modified by temperature remains unsettled.
Methods: A stratified time-series analysis was conducted to examine whether the effects of particulate matter less than 10 μm in aerodynamic diameter (PM_{10}) on mortality was modified by temperature in eight Chinese cities. Poisson regression models incorporating natural spline smoothing functions were used to adjust for long-term and seasonal trends of mortality, as well as other time-varying covariates. The bivariate response surface model was applied to visually examine the potential interacting effect. The associations between PM_{10} and mortality were stratified by temperature to examine effect modification.
Results: The averaged daily concentrations of PM_{10} in the eight Chinese cities ranged from 65 μg/m^3 to 124 μg/m^3, which were much higher than in Western countries. We found evidence that the effects of PM_{10} on mortality may depend on temperature. The eight-city combined analysis showed that on "normal" (5th–95th percentile) temperature days, a 10-μg/m^3 increment in PM_{10} corresponded to a 0.54% (95% CI, 0.39 to 0.69) increase of total mortality, 0.56% (95% CI, 0.36 to 0.76) increase of cardiovascular mortality, and 0.80% (95% CI, 0.64 to 0.96) increase of respiratory mortality. On high temperature (>95th percentile) days, the estimates increased to 1.35% (95% CI, 0.80 to 1.91) for total mortality, 1.57% (95% CI, 0.69 to 2.46) for cardiovascular mortality, and 1.79% (95% CI, 0.75 to 2.83) for respiratory mortality. We did not observe significant effect modification by extreme low temperature.
Conclusions: Extreme high temperature increased the associations of PM_{10} with daily mortality. These findings may have implication for the health impact associated with both air pollution and global climate change.

1. Introduction

China is one of the countries with exceptionally high particulate matter (PM) pollution in the world (Kan et al., 2009). Short-term exposure to PM has been linked to increased risk of mortality (Pope and Dockery, 2006). Temperature has long been recognized as a physical hazard, and is associated with a wide range of adverse health effects (Basu and Samet, 2002). Typically, a U-shaped relationship between temperature and daily mortality is observed with mortality risk decreasing from the lowest temperature to an inflection point and then increasing with higher temperature (Kan et al., 2003). The effect of temperature on mortality may be different in areas with different weather patterns, latitudes, air pollution levels and prevalence of air-conditioning systems (Basu and Samet, 2002).

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The rapid build-up of greenhouse gases is expected to increase not only mean temperature but also temperature variability. Extreme temperature has been associated with increased risks of mortality and morbidity (Huang et al., 2010; Ma et al., 2011). Recently, interest has been focused on the possible interacting effect of air pollution and extreme temperature (Carder et al., 2008; Katsouyanni et al., 1993; Li et al., 2011; Qian et al., 2008; Ren and Tong, 2006; Ren et al., 2006, 2008; Roberts, 2004; Stafoggia et al., 2008; Zanobetti and Schwartz, 2008). However, whether the health effect of air pollution is modified by temperature remains unsettled. For example, Samet et al. found little evidence that weather conditions modified the effect of pollution (Samet et al., 1998), while Ren et al. observed that temperature significantly modified the health effects of PM in Brisbane, Australia (Ren and Tong, 2006). Moreover, most of these studies were conducted in Australia, North America and Europe, and only a small number of studies have been conducted in China, the largest emitter of carbon dioxide (CO_2) in the world (Li et al., 2011; Qian et al., 2008). The need of such kinds of studies remains in Chinese cities, where characteristics of outdoor air pollution (e.g., air pollution level and mixture), meteorological conditions, and sociodemographic patterns of local residents may differ from those in Western countries.

In this study, we did a stratified time-series analysis to examine whether extreme temperature modified the effect of particulate matter less than 10 μm in aerodynamic diameter (PM_{10}) on daily mortality in eight Chinese cities. We considered PM_{10} because the current Chinese Air Quality Standard includes PM_{10} only among various PM metrics.

2. Methods

2.1. Data

The eight Chinese cities include Guangzhou, Hangzhou, Shanghai, Shenyang, Suzhou, Taiyuan, Tianjin, and Wuhan (Fig. 1). These cities have different geographic features and weather patterns. Three (Shenyang, Taiyuan and Tianjin) and five (Guangzhou, Hangzhou, Shanghai, Suzhou, and Wuhan) cities are located in the north and south part of China, respectively. Our study areas were restricted to the urban areas of these cities, due to inadequate air pollution monitoring stations in the suburban areas.

Daily mortality data of urban residents were obtained from the Municipal Center for Disease Control and Prevention in each city. The causes of death were coded according to the International Classification of Diseases, 10 (ICD-10). The mortality data were classified into deaths due to total non-accidental causes (ICD-10: A00-R99), cardiovascular disease (ICD-10: I00-I99), and respiratory disease (ICD-10: J00-J98).

The PM_{10} data were collected from the National Air Pollution Monitoring System (NAPMS) that were in the China National Quality Control for air monitoring network. The daily (24-h) average concentrations of PM_{10} were measured using the tapered element oscillating microbalance (TEOM) method. Chinese government has mandated detailed quality assurance and quality control programs at the NAPMS providing the PM_{10} data. For the calculation of 24-h mean concentrations, at least 75% of the one-hour values must be available on that particular day. If a station had more than 25% of the values missing for the whole period of analysis, the entire station was excluded from the analysis. The location of monitoring stations are mandated not to be in the direct vicinity of traffic or of industrial sources, and not to be influenced by local pollution sources and should also avoid buildings, or those that house large emitters such as coal-, waste-, or oil-burning boilers, furnaces, and incinerators. In each city, the daily PM_{10} concentrations were averaged from the available monitoring results across various stations.

Meteorological data (daily mean temperature and relative humidity) were provided by the National Meteorological Information Center (CMA) of China.

2.2. Statistical methods

Daily death, air pollution and weather data are linked by date and therefore were analyzed with a time-series design (Zeger et al., 2006). We used the generalized additive model (GAM) to analyze the daily mortality, PM_{10}, and temperature data. Because daily death numbers typically follow a Poisson distribution, the core analysis was a GAM with log link and Poisson error that accounted for smooth fluctuations in daily death numbers (Bell et al., 2004). The same analytical protocol has been used in the Public Health and Air Pollution in Asia (PAPA) project to investigate the short-term effects of air pollution on daily mortality in four Asian cities (Kan et al., 2008; Wong et al., 2008).

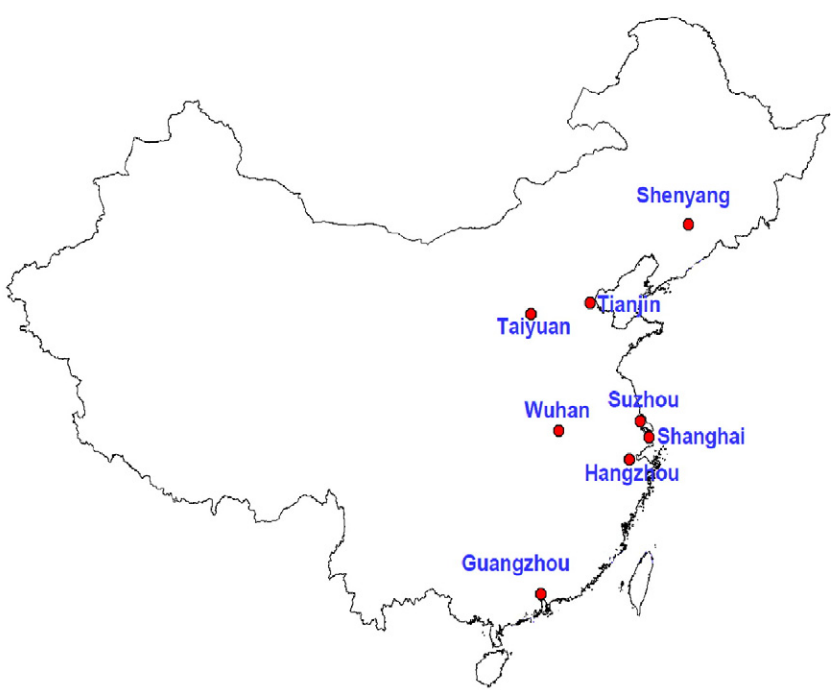

Fig. 1. Location of eight Chinese cities.