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Ambient air pollution, temperature and out-of-hospital coronary deaths in Shanghai, China

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ABSTRACT

Few studies have evaluated the effects of ambient air pollution and temperature in triggering out-of-hospital coronary deaths (OHCDs) in China. We evaluated the associations of air pollution and temperature with daily OHCDs in Shanghai, China from 2006 to 2011. We applied an over-dispersed generalized additive model and a distributed lag nonlinear model to analyze the effects of air pollution and temperature, respectively. A 10 μg/m^3 increase in the present-day PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO were associated with increases in OHCD mortality of 0.49%, 0.68%, 0.88%, 1.60% and 0.08%, respectively. A 1 °C decrease below the minimum-mortality temperature corresponded to a 3.81% increase in OHCD mortality on lags days 0–21, and a 1 °C increase above minimum-mortality temperature corresponded to a 4.61% increase over lag days 0–3. No effects were found for in-hospital coronary deaths. This analysis suggests that air pollution, low temperature and high temperature may increase the risk of OHCDs.

1. Introduction

Coronary heart disease (CHD) is the most common cause of death worldwide, and led to nearly 7 million deaths in 2010 (Lozano et al., 2013). Sudden cardiac death (SCD) often occurs with little warning and leads to death within an hour (Engdahl et al., 2002). SCD is important because it may happen in CHD patients who were previously stable, or who were not even recognized to have the disease (Zipes, 2005). Because CHD constitutes the major cause of SCD and most SCD occurs outside the hospital setting, out-of-hospital coronary death (OHCD) is regarded as an approximate surrogate of SCD (Forastiere et al., 2005; Goraya et al., 2003). As the largest developing country in the world, China has changed its disease spectrum in the last few decades, with cardiovascular diseases becoming the primary cause of death. SCD is estimated to emerge as an important public health burden in China, especially in developed areas such as Shanghai (Zhang, 2009).

Identifying the triggers of OHCDs is of public health significance. Previous investigators have found that short-term exposure to ambient air pollution can trigger SCD or OHCD events (Forastiere et al., 2005; Serinelli et al., 2010; Teng et al., 2014). Nevertheless, this evidence is quite scarce in developing countries such as China, where the air pollution problem is more severe than in developed countries. Actually, the different air pollution mixture in China may result in risk estimates different from those already reported in developed countries. Outdoor temperature serves as another major ambient risk factor affecting human health. Seasonal trends of SCD have been widely observed, and a recent study reported that extreme temperatures, both cold and hot, posed significant risks for OHCDs (Chen et al., 2014). Conversely, because both ambient air pollution and extreme temperatures increase the risk of OHCD, it is important to also consider how in-hospital coronary deaths (IHCDs) are affected by these ambient exposures, as IHCD also accounts for almost one half of coronary deaths. However, few studies have explored this issue.

Therefore, the primary objective of this study was to investigate the short-term association of ambient air pollution and temperature with OHCD in Shanghai, China. The results were then compared with the effects of these ambient exposures on IHCD.

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2. Methods

2.1. Data collection

Shanghai, the largest city in China, is situated at the tip of the Yangtze River Delta in the east of China and has a moderate subtropical climate. Our analysis was restricted to permanent residents living in the nine urban districts of Shanghai (approximately 6.5 million in 2008).

We obtained daily deaths caused by CHD during the period of 1 January 2006 to 31 December 2011 from the Center for Disease Control and Prevention. Deaths primarily due to CHD were identified by codes I20–I25, according to the Tenth Revision of the International Classification of Disease with codes I20–I25. In Shanghai, death certificates were completed at the time of death either by community doctors for deaths at home, or by hospital doctors for deaths at hospitals. The coding was determined by physicians according to patients' symptoms, inquiries, complaints, and results of a medical inspection or descriptions from decedents' relatives. According to death certificates, OHCD refers to deaths occurring outside of a hospital (e.g., at home, or in a public place, ambulance car or emergency room). Individuals who died in an emergency room almost had experienced a heart attack outside of the hospital, and were thus considered to be OHCDs. IHCDs refer to deaths occurring in a hospital.

We collected daily air pollutant concentrations from the database of the Shanghai Environmental Monitoring Center. Air pollutants included: inhalable particulate matter (particulate matter with an aerodynamic diameter less than 10 μm, PM_{10}), fine particulate matter (particulate matter with an aerodynamic diameter less than 2.5 μm, $PM_{2.5}$), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3). The 24 h mean concentrations for PM_{10}, SO_2, NO_2, CO and O_3 were simply averaged from six fixed-site stations located in six urban districts (Hongkou, Jing'an, Luwan, Putuo, Xuhui, and Yangpu; see Fig. 1). Because $PM_{2.5}$ was not a criteria air pollutant in China during our study period, only one monitor (Putuo station) measured $PM_{2.5}$ concentrations on a daily basis. The Chinese government has mandated detailed quality assurance and quality control programs at each monitoring station. The location of the monitoring stations was mandated to not be in the direct vicinity of traffic, industrial pollution or other local pollution sources, and to not be influenced by buildings or large housing emitters, such as coal-, waste- or oil-burning boilers, furnaces and incinerators. Therefore, the air pollutant measurements represent the levels of exposure to unban background air pollution in the general population.

Daily weather data (mean temperature and relative humidity) were collected from the Xujiahui Station of Shanghai Meteorological Bureau (see Fig. 1).

2.2. Statistical analysis

In environmental epidemiology, the time-series approach is widely used to investigate short-term associations of air pollution and temperature with adverse health outcomes (Chen et al., 2012; Ma et al., 2014). A generalized additive model (GAM) with a quasi-Poisson link was used to estimate the short-term associations of ambient air pollution and temperature with OHCD mortality in this study.

For estimating the effects of air pollutants, we introduced several covariates in the GAM: (1) a natural cubic smooth function of calendar day with 7 degrees of freedom (*df*) per year to exclude unmeasured long-term and seasonal trends in CHD mortality (Peng et al., 2006); (2) natural smooth functions with 6 *df* for the same-day mean temperature and 3 *df* for the same-day relative humidity to exclude potential nonlinear confounding effects of weather conditions (Chen et al., 2012); (3) an indicator for the day of week. Each of the six pollutants was introduced into the model one a time. We estimated the effects of air pollutants on the present day (lag 0), the previous day (lag 1) and two days previous (lag 2), because prior studies have suggested a generally immediate effect of air pollution (Chen et al., 2012; Dominici et al., 2006). Estimates were presented as the percent increase in daily mortality and its 95% confidence intervals (CIs) associated with a 10 $\mu g/m^3$ increase in air

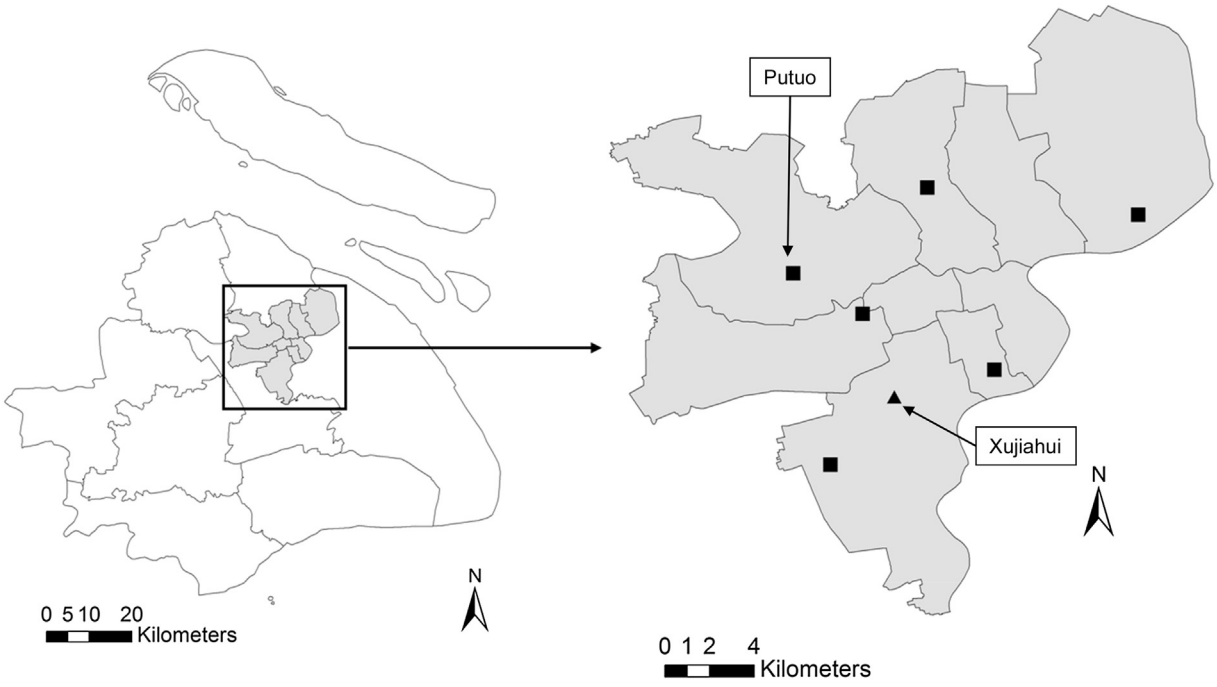

Fig. 1. The map of air quality monitoring stations and the weather station in this study.