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Short-term exposure to ambient air pollution and coronary heart disease mortality in 8 Chinese cities☆

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A B S T R A C T

Background: Coronary heart disease (CHD) accounted for a large fraction of death globally. The association between air pollution and CHD has been reported, but evidence from highly-polluted regions was scarce. We aimed to estimate the acute effects of outdoor air pollution on daily CHD mortality in China.

Methods: We collected daily CHD deaths in 8 large Chinese cities from 1996 to 2008. We firstly obtained the city-specific effect estimates of air pollution using generalized additive models with quasi-Poisson regression, controlling for time trends, meteorological indicators and day of the week. The random-effect model in meta-analysis was used to pool the exposure–response relationships.

Results: We identified a total of 0.13 million CHD deaths. On average, an increase of 10 μg/m^3 in 2-day moving average concentrations of particulate matter ≤ 10 μm in aerodynamic diameter (PM_{10}), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) was significantly associated with increases of 0.36% [95% confidence intervals (CIs): 0.12%, 0.61%], 0.86% (95% CIs: 0.30%,1.41%) and 1.30% (95% CIs: 0.45%, 2.14%) in daily CHD mortality over the 8 Chinese cities, respectively. The pooled exposure–response curves were almost linear and no apparent thresholds were identified. The effects were more pronounced in cities with lower levels of air pollution. The effects of PM_{10} and NO_2 were more robust than SO_2.

Conclusion: Our findings contributed to the very limited evidence regarding the hazardous effects of ambient air pollution on CHD mortality in highly-polluted regions such as China.

1. Introduction

Ambient air pollution is formed by a heterogeneous group of particulate matter (PM) and gaseous pollutants, including sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide and ozone. They vary appreciably in nature and sources. All these pollutants are mainly originated from industry- and traffic-related combustion process, and PM and ozone can also be formed by atmospheric chemical reactions (i.e., secondary sources).

Coronary heart disease (CHD), also known as ischemic heart disease, killed almost 7 million people in 2010 worldwide, accounting for the largest fraction of death causes and years of life lost [1]. Different magnitude of the short-term associations between air pollutants and CHD risk has been previously reported in North America [2,3], Europe [4–6] and developed Asian countries [7–9]. For instance, in a systematic review and meta-analysis on myocardial infarction (MI), fine particulates (PM with an aerodynamic diameter ≤2.5 μm, $PM_{2.5}$) had a 4-fold higher risk than inhalable particulates (PM with an aerodynamic diameter ≤10 μm, PM_{10}), and all gaseous pollutants other than ozone were significantly associated with MI risk.

As the largest developing country, China is one of the countries with the severest air pollution problems in the world. For example, according to statistics by the World Health Organization, China was the 15th-highest country with annual PM_{10} concentrations of 98 μg/m^3 in 2009 [10]. It was estimated that CHD led to 0.95 million deaths annually in China [11]. Nevertheless, epidemiological studies examining the associations between air pollution and CHD mortality were quite scarce in this country [12]. Further, exposure–response relationships between air pollution and CHD in China may differ from those reported in developed countries because of differences in levels and chemical components of air pollution mixture, as well as in socioeconomic susceptibility in populations [13]. Therefore, the exposure–response relationship in regions

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with high air pollution levels (such as China) is still unclear and consequently warrants exploration.

Therefore, the objective of this study was to investigate the short-term associations between air pollution and daily CHD mortality in 8 large Chinese cities. This analysis is a part of the China Air Pollution and Health Effects Study (CAPES). We chose 3 criteria air pollutants (PM_{10}, SO_2 and NO_2) because only them were routinely monitored in China during our study period.

2. Methods

2.1. Mortality data

According to the CAPES project, we collected daily mortality data from 8 Chinese cities including Beijing, Shanghai, Guangzhou, Hong Kong, Shenyang, Tangshan, Taiyuan and Xi'an (see Fig. 1). Our analysis was restricted to the urban areas because both death registry and air quality monitoring system have not been well established in suburban and rural areas in China.

Daily CHD mortality data were obtained from the local Municipal Center of Disease Control and Prevention in each city, while data in Hong Kong was extracted from the Census and Statistics Department. A CHD death was defined according to the primary death cause in terms of ICD-10 (codes I20–I25). 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. Then, the deaths were aggregated on a daily basis. The study period varied between 1996 and 2008 from city to city, depending on data availability.

2.2. Environmental data

We collected daily concentrations of PM_{10}, SO_2, and NO_2, from the National Air Quality Monitoring System, which is certified by the Ministry of Environmental Protection of China. The data in Hong Kong was extracted from its Environmental Protection Department. Hourly concentrations of these pollutants were measured using tapered element oscillating microbalance, ultraviolet fluorescence, and chemiluminescence methods, respectively. Daily 24-hr average concentrations in a city were derived from the average of available hourly data measured in all monitors. For the calculation of 24-hr averages, at least 75% hourly concentrations had to be available in a single day. If more than 25% of the data in a monitoring station was missing in the whole study period, the entire station would be excluded. There were 2–12 monitoring stations in each city. According to the Chinese governmental rules, the location of the monitoring stations was mandated not to be in the direct vicinity of traffic, industrial and other local pollution sources, and not to be influenced by buildings or large housing emitters, such as coal-, waste- or oil-burning boilers, furnaces and incinerators. The determination for the location of each monitor was assured by the uniform national quality control. Therefore, the measurements can represent the exposure levels of unban background air pollution in the general population.

To control for potential confounding from weather conditions, we also collected daily mean temperature and relative humidity in each city.

2.3. Statistical analysis

In the first stage, we investigated the city-specific association between an air pollutant and daily CHD mortality using time-series regression models. This method has the advantage of automatically controlling for time-invariant confounders (such as the structure of age, sex, fat or thin, socioeconomic status) in the population level by examining the same population repeatedly over time. We applied generalized additive models (GAM) with quasi-Poisson regression because daily CHD deaths typically followed an overdispersed Poisson distribution [14]. 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 time trends longer than 2 months in CHD mortality [15]; (2) an indicator variable for "day of

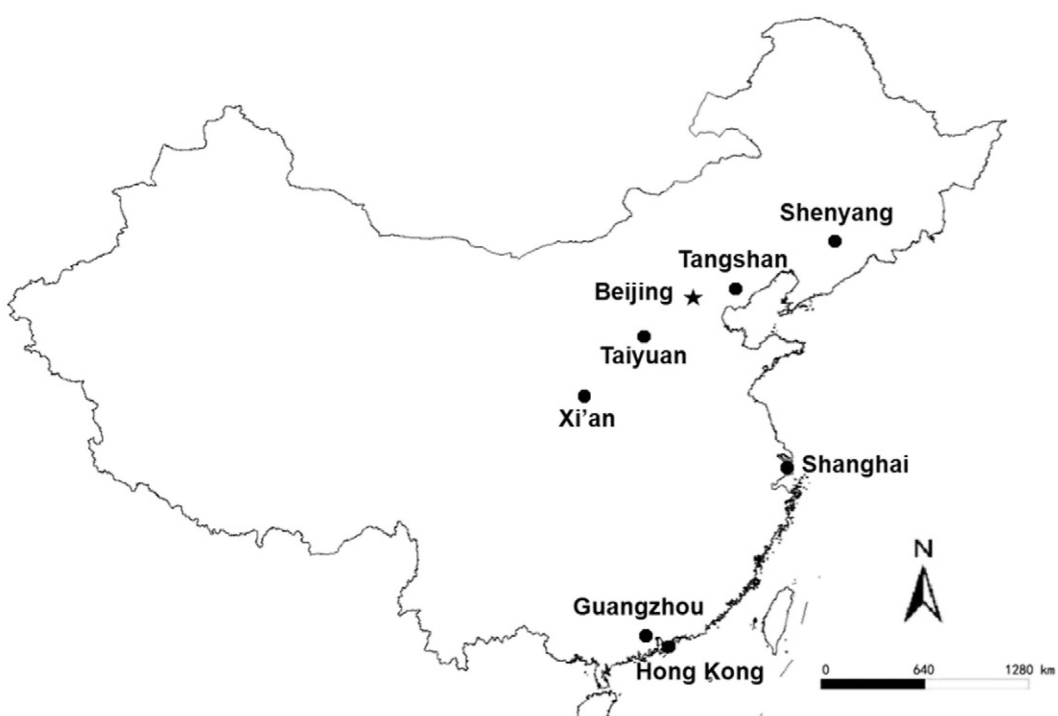

Fig. 1. Map of cities in this study.