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Effect of ambient air pollution on daily mortality rates in Guangzhou, China

Ignatius Tak Sun Yu [a], Yong hui Zhang [b], Wilson Wai San Tam [a], Qing Hua Yan [b], Yan jun Xu [b], Xiao jun Xun [b], Wei Wu [b], Wen Jun Ma [b,c,*], Lin Wei Tian [a], Lap Ah Tse [a], Xiang Qian Lao [a]

[a] School of Public Health and Primary Care, Faculty of Medicine, The Chinese University of Hong Kong, China
[b] Center for Disease Control and Prevention of Guangdong Province, Guangzhou, China
[c] Guangdong Institute of Public Health, 176, Xin Gang Xi Road, Guangzhou, China

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ABSTRACT

We aimed to investigate the effects of ambient air pollutants on daily mortality in a relatively stable and homogeneous population in Guangzhou, China. Daily mortality, air pollution, and weather data between 2006 and 2009 were collected. The generalized additive model with poison regression was used to estimate the excessive risks (ERs) of air pollutants (PM_{10}, SO_2, and NO_2) on total, cardiovascular and respiratory mortality. The effects of lag0–1 were the greatest for total non-accidental and cardiovascular deaths. The increments of 10 $\mu g\,m^{-3}$ in SO_2, NO_2, and PM_{10} were associated with ERs of 1.54% (95%CI: 1.03–2.06%), 1.42% (95%CI: 1.06–1.78%), and 1.26% (95%CI: 0.86–1.66%) respectively for total non-accidental deaths, and 2.28% (95%CI: 1.40–3.16%), 1.81% (95%CI: 1.20–2.41%), and 1.79% (95%CI: 1.11–2.47%) respectively for cardiovascular deaths. For persons who died from respiratory disease, however, the maximum effects occurred at lag0. The ERs for SO_2, NO_2, and PM_{10} were 1.36% (95%CI: 0.23–2.50%), 1.47% (95%CI: 0.66–2.29%) and 0.93% (95%CI: 0.03–1.83%), respectively. The effects of the three air pollutants on mortality were stronger in elderly and in women. The ERs in the present study were higher than those reported in Europe, the U.S., and most other Asian cities. Our findings show relatively higher ERs of daily mortality by ambient air pollutants in the center of Guangzhou, China, compared with estimates in other cities. Further studies with accurate exposure measurement among homogeneous population are needed to evaluate the precise magnitudes of the effects of the air pollutants.

1. Introduction

Ambient air pollution is a global public health concern that is estimated to cause approximately two million premature deaths per year worldwide (WHO, 2008). Air pollution is particularly alarming in China. Based on World Bank data, China has 16 of the planet's 20 most air-polluted cities, and over 400,000 premature deaths a year are blamed on ambient air pollution in China (Watts, 2005).

Time-series designs have been widely employed in air pollution studies because they use routinely-collected data. Two sources for these data are ambient air pollution monitoring and health surveillance. The data are generally available publicly, and thus they are fairly easy and inexpensive to obtain (Sheppard et al., 2005). A number of time-series studies has confirmed that ambient air pollution is associated with increases in mortality, hospital admissions, and visits to both general practitioners and emergency rooms. However, most of these studies were conducted in European and North American cities. Only a small number have been conducted in the developing countries of Asia (Health Effects Institute, 2004), where air pollution resulting from the rapid economic development of recent decades has become a serious public health problem. In China, time-series studies concerning air pollution and daily mortality have been conducted for several cities including Hong Kong (Wong et al., 2002, 2008b), Shanghai (Kan et al., 2008), Tianjin (Guo et al., 2010), Wuhan (Qian et al., 2007), Shenyang (Xu et al., 2000) and Anshan (Chen et al., 2010). The results show that air pollution levels in these cities are associated with increases in daily mortality rates. These results are consistent with previous Western studies.

Despite their proven success in air pollution research, time-series designs have their limitations. The characteristics for the individual people in the target population in large time-series studies were generally absent and therefore could not be taken into account in the analysis. Previous studies have revealed mortality risks in Asian cities that were higher than those in Western cities (Wong et al., 2008b). These differences have been

* Corresponding author. Guangdong Institute of Public Health, 176, Xin Gang Xi Road, Guangzhou, China. Tel.: +86 20 84458530; fax: +86 20 89104239.
E-mail address: mwj68@tom.com (W. J. Ma).

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partially attributed to differences in population characteristics and air pollution levels, as well as the chemical composition. Also, the accuracy of the population risk estimates is compromised by the fact that such measurements are generally taken only at central monitoring sites (Brunekreef and Holgate, 2002). Most previous time-series air pollution studies have covered a large geographical area with a limited number of monitoring stations. Exposure measurement error has been cited as a major limitation in these studies (Sheppard et al., 2005; Wilson et al. 2005). In addition, a population living in a large geographical area is likely to be more heterogeneous with respect to demographic characteristics than a population living in a small geographical area. Some investigators have pointed out that the tendency in time-series studies to sample small geographical areas with relatively homogeneous populations can reduce the exposure error and thus lead to better risk estimates of air pollution (Chen et al., 2007; Jerrett et al., 2005; Wilhelm and Ritz, 2005; Wilson et al., 2007). More such studies are needed if we are to optimize these risk estimates. As there have been no studies of this type in subtropical cities, we conducted a time-series study of the impact of air pollution on mortality rates in Guangzhou, a large city in southern China, from 2006 to 2009. Guangzhou is located in a subtropical area and has typical subtropical weather. We focused on the city center, which has an area of 92.9 km^2 and a relatively stable, homogeneous population of 1,886,800 permanent residents (Lin and Ma, 2007; Hu et al., 2009).

2. Methods

2.1. Setting

Guangzhou, the capital of Guangdong province, is located in southern China about 180 km north of Hong Kong. Before China's open policy of 1979, Guangzhou had six districts (Yue Xiu, Li Wan, Bai Yun, Hai Zhu, Huang Pu and Tian He) with a total area of 1162.60 km^2. As of 1979, Guangzhou had 3.85 million residents, and the mobility of the population was low. During the last three decades of rapid economic development, six more districts were added and several million migrant workers flooded into Guangzhou city. This influx increased the area of the city to 7434.40 km^2. In 2006, the population reached 11.51 million (7.60 million permanent residents and 3.91 million migrants). Fig. 1 presents a district map of Guangzhou showing the locations of the nine automatic, online air pollution monitoring stations.

The residents of two districts in Guangzhou city (Yue Xiu and Li Wan) were selected as the sample for the present study. These districts combined have an area of 92.90 km^2 and are home to 1.88 million residents. These districts were chosen for two reasons. First, there are three monitoring stations covering these two relatively small districts. Previous studies have shown that one or a few monitoring sites are not sufficient to accurately depict a wide area of population exposure due to the intra-urban variation. However, pollutant concentrations from stations monitoring a small area have been reported as having relatively smaller exposure error (Jerrett et al., 2005; Wilhelm and Ritz, 2005; Wilson et al., 2005, 2007). Second, because most of those living in these two districts are permanent residents, the mortality data are also of high quality.

The other districts were excluded because of either one of the following reasons: First, there are no automated monitoring stations in some of these districts, or there is only one monitoring station covering a large area, the pollution data from the stations may not well reflect the exposure for the residents; Second, most of these districts are newly developed and thus have a large proportion of migrants. This is a problem because the family of the deceased must report and cancel the deceased's household registration at the local Public Security Station, which requires that they obtain a death certificate from the hospital. In the case of migrants, who are not permanent residents of Guangzhou, the cancellation must be done in the person's home town, not Guangzhou, thereby adversely affecting the collection of the mortality data. Third, the demographic and socioeconomic characteristics of the population are different in the new than in the old districts, which can bias the data on the health effects of the pollutants (Wilson et al., 2007; Wong et al., 2008a)

The air pollution data for the period ranged from January 1, 2006 to December 31, 2009 were obtained from the Guangzhou Environmental Monitoring Center. Because of the relatively small area covered in the present study, we collected data from a longer period (4 years) to ensure sufficient statistical power. The Center is part of a nationwide network of monitoring stations and reports daily to the China Environmental Monitoring Chief Station. In 2003, the Center passed the national laboratory accreditation evaluation, which confirms that it met the ISO/IEC 17025 requirements, and thus received the appropriate certification. None of the Center's nine monitoring stations are close to traffic and industrial sources. The pollutants collected from these stations included nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter with an aerodynamic diameter less than 10 μm (PM_{10}). The pollutants measured in the stations are effectively over 45 min per hour, with the daily average based on over 18 h of measurement with at least one average per hour (Lam et al., 2005). Meteorological data (daily mean temperature, relative humidity, and wind speed) were collected from the Guangzhou Observatory.

The mortality data were obtained from the Guangdong Provincial Center for Disease Control and Prevention (GDCDC). These data are comparable to the data collected by the Public Security Stations. The records provide information on the deceased's gender, date of death, age at death, and the underlying cause of death. The latter was coded using the International Classification of Diseases, Tenth Revision (ICD-10) (WHO, 1993). With accidental deaths being excluded from the present study, the mortality data were divided into the following causal categories: total non-accidental causes (ICD-10: A00-R99), cardiovascular disease (ICD-10: I00-I99), and respiratory disease (ICD-10: J00-J98).

2.2. Statistical analysis

As daily mortality counts are non-negative discrete integers representing rare events, they typically follow a Poisson distribution (Ostro et al., 2006). A generalized additive model (GAM) with Poison regression was therefore used to assess the relationship between daily mortality and air pollution. First, we generated core models limited to variables representing days of the week (DOW), time trends, and two weather parameters (temperature and humidity). DOW was a dummy variable, whereas the time trend and weather variables were included using smoothing spline functions. Degrees of freedom were determined by generalized cross-validation methods (Gu, 2002). Residual plots were used to examine whether there were discernable patterns for the core models. These models can be generically represented as:

$$\log[E(Y_t)] = \text{intercept} + s\,(\text{time}) + s\,(\text{temperature}) + s\,(\text{humidity}) + \text{DOW},$$

where $E(Yt)$ is the expected number of deaths on day t. The smooth function s captures the nonlinear relationships of the covariates of time trend and the weather parameters with daily mortality. Daily mean temperature and relative humidity were used in all models to control for confounding.

After the core models were established. We included the three pollutants in the regression models and analyzed the relationships