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The short term burden of ambient particulate matters on non-accidental mortality and years of life lost: A ten-year multi-district study in Tianjin, China☆

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ABSTRACT

Years of life lost (YLL) is a more informative and accurate indicator than daily death counts for assessing air pollution related premature death. However, there is limited evidence available about the relationship of air pollution with YLL, especially in China. We conducted a ten-year (from January 1st, 2001 to December 31st, 2010) multi-district time-series study to estimate the effects of ambient particulate matter with an aerodynamic diameter of less than 10 μm in size (PM_{10}) on daily non-accidental deaths and YLL in six districts of Tianjin, China. Meta-analysis was used to merge the results of the six districts. We found that the increase of PM_{10} was significantly associated with daily death and YLL in the six districts, except with the YLL in Heping district. 10 $\mu g/m^3$ increases in PM_{10} were associated with the maximum increases in excess risk (ER) of death counts of 0.33% (95% confidence interval [CI]: 0.25%, 0.41%) at lag01 and in YLL of 0.80 (95%CI: 0.47, 1.13) person year at lag01 for the combined effects of six districts, respectively. Moreover, the associations of PM_{10} on daily death counts and YLL were stronger in the elder people (≥65 years) than those in the younger ones (<65 years). These findings may help to shed light on the policy-making of PM-control in China and provide useful information for the protection of susceptible population.

1. Introduction

Ambient particulate matter (PM) is one of the most important environmental issues in worldwide, especially in China, due to the effects of the hazardous haze in recent years. Several previous studies have demonstrated the statistically significant associations between ambient PM and mortality in the developed countries and in some mega-cities in China (Andersen et al., 2004; Chen et al., 2012; Samoli et al., 2008; Wong et al., 2010). However, using mortality as a surrogate for the health effects caused by ambient PM exposure might fail to take into account the influence of the age on death (Guo et al., 2013). This might lead to the inconclusive evidence for the health effects and the ignorance of the severity and duration of the adverse health effects of ambient PM (Gao et al., 2015). Therefore, a more informative quantifiable indicator is necessary for the estimation of the associations between health effects and ambient PM (Geelen et al., 2009).

Years of life lost (YLL) is an indicator of disease burden that could take the premature death and life expectancy at death into consideration (Guo et al., 2013; Yang et al., 2015). Besides, it is more accurate than mortality to measure premature death and excess mortality (Brustugun et al., 2014; He et al., 2016). However, to date, few studies in China have used YLL as the health endpoint to assess the health effects of ambient PM (Guo et al., 2013; He et al., 2016; Lu et al., 2015). Nevertheless, these studies were conducted in a very short study period (no more than 4 years). Thus, epidemiological studies covering a long study period and a large study population are needed to robustly evaluate the association between ambient PM and YLL.

Therefore, this study was conducted from 2001 to 2010 (ten-year) to investigate the effects of ambient particulate matter with an aerodynamic diameter of less than 10 μm in size (PM_{10}) on daily non-accidental deaths and YLL in Tianjin, China.

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2. Materials and methods

2.1. Study design and population

We used a multi-district ten-year (from January 1st, 2001 to December 31th, 2010) time-series study design to investigate the potential effects of PM_{10} exposures on non-accidental death counts and YLL in Tianjin, China. Six urban districts of Tianjin including Hedong district, Hebei district, Hexi district, Heping district, Nankai district and Hongqiao district were selected in this study. The population of each district was shown in Table 1 and a total of 3 922 011 citizens were included in this study (Date was from National Bureau of Statistics of China).

2.2. Mortality data

Daily mortality data on non-accidental death between January 1st, 2001 and December 31st, 2010 was obtained from Tianjin Centers for Disease Control and Prevention. The causes of non-accidental death were classified and coded based on the International Classification of Diseases 10th version (ICD-10: A00-R99) (World Health Organization, 1993). The information of death date, gender and age were also included in the database. The data were stratified by age (<65 years and ≥65 years) in accordance with similar studies (Guo et al., 2013; Lu et al., 2015).

2.3. YLL data

YLL data was estimated using Standard Expected Years of Life Lost approach based on World Health Organization (WHO) standard life table for YLL (Supplementary material, Table S1). YLL for each death was calculated by matching age to the life table. Daily YLL were the sum of the YLL for all deaths on that day (Guo et al., 2013). Then the sums were stratified by age group (<65 years and ≥65 years) (Guo et al., 2013; Lu et al., 2015).

2.4. Exposure assessment

During the study period, the daily average concentrations of PM_{10} from the city central air-monitoring stations of each district were obtained from the Tianjin Environmental Monitoring Center. Each district has one central air-monitoring station and the location of each station was shown in Fig. 1. Daily meteorological (including temperature and relative humidity) data was obtained from the Tianjin Meteorological Bureau. There was only one monitoring site for meteorological data in Tianjin, which was located at Hexi district. There were less than 0.5% missing data of PM_{10} and 1% missing data of meteorological data. The missing data of PM_{10} and meteorological data was imputed by the median of the days before and after.

2.5. Statistical analysis

Generalized additive model (GAM) was used to estimate the burden of PM_{10} on daily non-accidental death counts and YLL of each district. Because the dependent variable of daily YLL were normally distributed (Supplemental Material, Fig. S1), we used a generalized linear regression model to assess its association with PM_{10} (J Yang et al., 2015). The model is as follows:

$$\mathrm{YLL}_t = \alpha + \sum_{i=1}^{q} \beta_i(X_i) + \sum_{j=1}^{p} f_j(C_j, df) + W_t(\mathrm{week})$$

Where YLL_t is the observed daily YLL at day t ($t = 1,2,3 \ldots 3652$); α is the intercept; β is the value of YLL associated with a unit increase in PM_{10}; X_i represents the daily mean concentrations of PM_{10} at day t; C_j is an array of confounding variables including time, daily temperature and daily relative humidity; f_j is the smooth functions; $W_t(week)$ is the dummy variables for day of week on day t, respectively. We applied the penalized spline function of time and 7 of degrees of freedom (df) per year (totally 70 df for ten years) to control the long-term trend and seasonality. We incorporated the penalized spline for temperature and relative humidity, in which 3 df was used (Samet et al., 2000; Y Yang et al., 2015). Because of the lagging effects of temperature, the 14-day moving average of temperature was used. As for relative humidity, only present day relative humidity was incorporated into the model considering little evidence of its confounding in current studies. We validated the model fit by checking the residuals to make sure that autocorrelation had been successfully removed. Moreover, we stratified analyses by age group (<65 years and ≥65 years).

Furthermore, we also investigated the association between daily death counts and PM_{10} in our study. Same independent variables were used as that in the YLL model, except that time series function with the Poission link, under a GAM framework, was used (Peng et al., 2006).

To estimate potentially delayed and cumulative exposure associations, we also investigated the lag effects of PM_{10} in the models. As previous studies showed that the effects of air pollution on mortality in day 0 (lag0) and day 1 (lag1) and cumulative effects in 2-day moving average concentrations of day 0 and day 1 (lag01) were strongest (Schwartz, 2000; Touloumi et al., 2004; Yang et al., 2013). Therefore, we fitted the models with lag structures from lag 0 to lag 1 day and 2-day moving average concentrations of day 0 and day 1 (lag01) to investigate the potential delayed and cumulative effects of PM_{10} on daily death counts and YLL. Moreover, we used an autocorrelation function in models to assess whether the residuals were independent over time, and no obvious autocorrelation was found (Supplementary material, Figs. S2 and S3).

To check the robustness of our models, we performed several sensitivity analyses by changing the lag day of relative humidity, degrees of freedom for time and temperature for associations of

Table 1
Characteristics of population and non-accidental deaths for each district in Tianjin during 2001–2010.

District	Population (thousand person)[a]			Non-accidental death counts (person)		
	Total	Age ≥ 65years	Age < 65years	Total	Age ≥ 65years	Age < 65years
Hedong district	712.2	83.1	629.1	47 803	36 733	11 070
Hebei district	632.6	84.2	548.4	48 928	37 648	11 280
Hexi district	785.1	96.9	688.2	48 576	37 881	10 695
Heping district	397.2	68.9	328.3	29 251	23 903	5348
Nankai district	848.7	103.5	745.2	53 554	41 819	11 735
Hongqiao district	546.1	72.7	473.4	42 165	32 607	9558
Total	3921.9	509.2	3412.7	270 277	210 591	59 686

[a] Data is from the 2010 statistical yearbook.