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Short-term effect of air pollution on asthma patient visits in Shanghai area and assessment of economic costs

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ABSTRACT

Backgrounds: Shanghai, in China, is one of the highest incidence cities for asthma morbidity. However, few studies have systemically explored the association of ambient air pollutants and asthma patients with economic costs.
Objectives: The study researched the link of short-term ambient air pollutants exposure and asthma patients in Shanghai. Furthermore, the economic cost was also assessed.
Methods: We applied the generalized addictive model (GAM) to analyze the association between ambient air pollutants and asthma patients with economic costs assessment.
Results: We investigated a total of 7200 asthma patient visits (inhabitant in Shanghai). A 10 $\mu g\,m^{-3}$ increase in the current day concentrations of SO_2, CO, NO_2, PM_{10}, O_3 and $PM_{2.5}$ corresponded to increase of 3.79% [95% CI: 0.84%, 6.83%], 0.27% [95% CI: 0.14%, 0.40%], 0.63% [95% CI: − 0.81%, 2.10%], 1.11% [95% CI: 0.38%, 1.85%], 0.23% [95% CI: 0.31%, 078%] and 1.27% [95% CI: 0.29%, 2.26%] in daily asthma patient visits. In economic cost level, the economic cost of asthma patients were attributed to ambient air pollutants (SO_2, CO, NO_2, PM_{10}, O_3 and $PM_{2.5}$) with 197 million USD losses per year. Among, the economic cost of asthma patient visits were attributed to SO_2, CO, NO_2, PM_{10}, O_3 and $PM_{2.5}$ with 101.30, 7.46, 17.15, 30.18, 6.39 and 34.50 million USD loss per year, respectively.
Conclusions: Short-term exposure to SO_2, CO, NO_2, PM_{10}, O_3 and $PM_{2.5}$ were linked to asthma patient visits increase in Shanghai areas. The economic cost of asthma patient visits were attributed to ambient air pollutants (SO_2, CO, O_3, PM_{10}, NO_2 and $PM_{2.5}$) with 197 million USD losses per year. The study strengthen our fundamental comprehending of impacts of ambient air pollutants on human health and economy burden.

1. Introduction

Air pollution adversely affects human health, including morbidity and mortality (Chiang et al., 2016; Li and Lin, 2014). Asthma is a kind of lung inflammatory disorder that affects all ages' people, and causes morbidity and mortality increase of human being (Athanazio, 2012; Rincon and Irvin, 2012). Globally, approximately 300 million people have asthma disease and a sustainedly increase in adults and children, which has been witnessed in recent decades. For example, the asthma patients have reached about 30 million in China in 2010 (D'Amato et al., 2015; Ober and Yao, 2011). The economic burden of asthma is considerable and associated with hospitalization, medications, and potential years of work lost due to morbidity and mortality (Einarson et al., 2016; Stirbulov et al., 2016). Obviously, asthma has imposed a heavy economic burden over past decade.

Many epidemiologic studies demonstrated an association of air pollution and asthma risks, which lead to the hospital patients increase (Loyo-Berrios et al., 2007; Makra et al., 2012; Raun et al., 2014). Further, evidences have showed that ambient air pollutant also might induce new-onset asthma (Guarnieri and Balmes, 2014; Jeebhay et al., 2014). For example, previous cohort study found that traffic-related emission can cause asthma onset in children (Jerrett et al., 2008). Modig L et al. shows that vehicle exhaust also lead to asthma onset among adults (Modig et al., 2009). Not all researches support a casual association of asthma and air pollution (Guarnieri and Balmes, 2014). With real-time monitoring of $PM_{2.5}$ in 2013, China newly supplemented the average concentrations of CO, O_3 and $PM_{2.5}$ as new indicators to assess air quality. Thus, investigating the impacts of ambient air pollutants on asthma patients have become a practical and significant possibility.

Kan et al. showed that NO_2 and SO_2 were significantly associated with emergency visits and hospital outpatient in Shanghai, and that exposure to SO_2 and NO_2 have an adverse health effect (Cai et al., 2014; Li et al., 2016; Meng et al., 2013). Shanghai is characterized by the

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northwest trade winds over the Mainland China, the southeast summer monsoon trade winds from the Western Pacific ocean. The boom of industrialization in Shanghai has led to a excessive release of ambient air pollutants (Cao et al., 2009). Levels of atmospheric PM have continually increased because of a rapid increase of motor vehicles, the expansion of urban area and the illegal biomass burning (Cao et al., 2015; Hu et al., 2016; Zhang et al., 2015). Thus, exploration of the relationship of air pollution and asthma in Shanghai area is significant.

In this study, we researched the relationship of asthma patient visits and ambient air pollutants: SO_2, CO, NO_2, PM_{10}, O_3 and $PM_{2.5}$ in Shanghai, China. We also assessed the effect of asthma patient visits on economic cost.

2. Materials & methods

2.1. Study area

Shanghai, is locating to the Yangtze River Delta in east China where has a distinct seasons, moderate subtropical climate and abundant rainfall. Shanghai had a population of 24.26 million in 2014 with an area of 6341 km^2, including 8 urban districts with area of 259 km^2 in Shanghai. These urban districts include Luwan, Yangpu, Pudong, Hongkou, Putuo, Xuhui, Jing'an and Qingpu (Fig. S1). These urban districts were investigated due to sufficient ambient air pollutants monitoring data.

2.2. Asthma patient visits

Data was extracted from Shanghai Pulmonary Hospital (asthma patient counts of 7200), which is a large of samples behaving random episodes. These data were selected because of representation. Asthma patient means that the clinic visits are related with respiratory disease symptoms. Samples are confirmed or suspected to asthma. The samples were selected according to the code in International Classification of Diseases (ICD), 10th revision (ICD-10) for all patients with asthma (ICD-10: J45, J45.0, J45.9, J 45.1). The samples information, including date of admission, diagnostic and residential address, were used in this study. The respiratory disease patients who lived in study areas were confirmed through the residential address.

2.3. Environmental data

Daily 8 h average for O_3 and daily 24 h average for SO_2, CO, NO_2, PM_{10} and $PM_{2.5}$ were acquired in Shanghai Environmental Monitoring Center (SEMC) during 22 January 2014–31 October 2015. The daily concentrations for these pollutants were obtained from the available monitoring data of eight fixed-site station. These fixed-site stations avoid the effect of industrial source or traffic. Moreover, the stations should also avoid furnaces, waste-burning boiled and buildings. Thus, the gathering data reflects the overall level of urban air pollution. If a station had more than 20% of the values missing for the all period of analysis, these data should be excluded. The meteorological data, including relative humidity and daily average temperature, were extracted at Shanghai Meteorological Bureau (SMB). The data was collected base on World Meteorological Organization standard. We promise that the data was authenticity and representative.

2.4. Statistical analysis

During 22th January 2014–30th October 2015, amount of 7200 asthma patient visits were counted. A time-series method is often used to explore the link of ambient air pollutants and health outcome (Huang et al., 2016). The link of ambient air pollutants and asthma patients were investigated by Generalized additive model (GAM) in this study. The data of holidays and weekends were deleted because it is not open in these days. Ambient air pollutants were acquired from SEMC, which is representative. Relative humidity and daily average temperature were collected from SMB.

Multiple linear regression models were applied to research the associations of asthma patient visits and the concentrations of ambient air pollutants (SO_2, CO, NO_2, PM_{10}, O_3 and $PM_{2.5}$) to which the patients were exposed (Zheng et al., 2015). After the consideration of underlying confounders and impact modifiers, the whole models were controlled for testing period, temperature, relative humidity.

To determine the potential non-linear exposure-response relationships, GAMs were used to estimate the internal connection of ambient air pollutants and asthma patient visits by examining the degrees of freedom of the fluent connection for every variable as one part of the model fixation procedure. The regulation variables were similar to those obtained by the linear regression. When we selected the final models for each ambient air pollutants, the potential confounding and modifying effect was examined. To avoid potential multi-collinearity of air pollutants, two-pollutant models were fitted to examine co-dependency according to the correlation structure.

Pearson correlation coefficient was calculated to explore the relationship of ambient air pollutants. GAM was applied to analyze the relationship of ambient air pollutants and asthma patient visits because of the co-variant of meteorological conditions in this study. We set up the models and then selected the pollutant's variables and analyze their impacts on asthma patient visits. We explored the impact of ambient air pollutants with different lag structures on asthma patient visits, including single-day lag (e.g. Lag 0) and multi-day lag (e.g. Lag 01). For instance, in single-day pollutant concentration, a Lag 0 means the pollutant concentration effect in current-day, and a Lag 1 means the concentration in previous-day. In multi-day Lag models, Lag 01 refers to 2 days moving mean of pollutants concentration of the current and previous day, and Lag 02 means 3-day moving average of ambient air pollutants concentration of the current and previous 2 days. We explored the impacts of single-pollutant and multi-pollutant on asthma patient. The 95% confidence interval (CI) was estimated as follows:

$$(Q_1 - Q_2) \pm 1.96 \times \sqrt{(SE_1^2 + SE_2^2)} \quad (1)$$

where Q_1 and Q_2 are the estimates, and SE_1 and SE_2 are the standard errors (Cao et al., 2009).

The analyses were carried out in R 2.11.1 through the GAM model (R Development Core Team, 2011). In order to compare with previous studies, we show per 10 $\mu g\,m^{-3}$ increase of ambient air pollutants concentration as the percent change in asthma patient visits.

3. Results

3.1. Influence of ambient air pollutants on asthma patient visits

Table 1 summarizes the asthma patient counts and environmental variables. Daily average concentrations were 50.5 $\mu g\,m^{-3}$ for $PM_{2.5}$, 68.3 $\mu g\,m^{-3}$ for PM_{10}, 106 $\mu g\,m^{-3}$ for O_3, 16.5 $\mu g\,m^{-3}$ for SO_2, 43.7 $\mu g\,m^{-3}$ for NO_2 and 780 $\mu g\,m^{-3}$ for CO. Meanwhile, the relative humidity and daily mean temperature were 70% and 18 °C, which is showing the subtropical climate in Shanghai. In general, SO_2, CO, NO_2, PM_{10}, O_3 and $PM_{2.5}$ had relative high correlated coefficients with each other except O_3 with SO_2, NO_2 and CO (Table 2).

Table 3 presents the single-pollutant model and multi-pollutant model results using exposure at current day (Lag 0). In two-pollutant model, the link of particulate matter ($PM_{2.5}$ and PM_{10}) with asthma morbidity decrease and statistically insignificant, but remained positive (except $PM_{2.5}$ with CO), after adding gaseous pollutant (SO_2, CO or O_3). However, NO_2 adjustment increased the associations and rendered them significantly. A 10 $\mu g\,m^{-3}$ increase in $PM_{2.5}$ and PM_{10}, after adjustment for NO_2, were associated with a 1.44% [95% CI: 0.29, 2.60] and 1.28% [95% CI: 0.41, 2.15] increase of asthma morbidity.

Following the results of multi-pollutants, we study the relationships