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Ambient fine and coarse particulate matter pollution and respiratory morbidity in Dongguan, China☆

Yiju Zhao [a], Shengyong Wang [b], Lingling Lang [c], Caiyan Huang [a], Wenjun Ma [d,*], Hualiang Lin [c,**]

[a] Department of Respirator Medicine, The Fifth People's Hospital of Dongguan, Dongguan, China
[b] Medical College, Jinan University, Guangzhou, China
[c] Guangdong Provincial Institute of Public Health, Guangdong Provincial Center for Disease Control and Prevention, Guangzhou, China
[d] Guangdong Provincial Center for Disease Control and Prevention, Guangzhou, China

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ABSTRACT

We estimated the short-term effects of particulate matter (PM) pollution with aerodynamic diameters ≤2.5 μm ($PM_{2.5}$) and between 2.5 and 10 μm (PM_c) on hospital outpatient visits due to overall and specific respiratory diseases, as well as the associated morbidity burden in Dongguan, a subtropical city in South China. A time-series model with quasi-Poisson link was used to examine the association between PM pollution and morbidities from respiratory diseases, COPD, asthma and pneumonia in Dongguan during 2013–2015. We further estimated the morbidity burden (population attributable fraction and attributable morbidity) due to ambient PM pollution. A total of 44,801 hospital outpatient visits for respiratory diseases were recorded during the study period. Both $PM_{2.5}$ and PM_c were found to be significantly associated with morbidity of overall respiratory diseases, COPD, and asthma. An IQR (interquartile range) increase in $PM_{2.5}$ at lag_{03} day was associated with 15.41% (95% CI: 10.99%, 20.01%) increase in respiratory morbidity, and each IQR increase in PM_c at lag_{03} corresponded to 7.24% (95% CI: 4.25%, 10.32%) increase in respiratory morbidity. We did not find significant effects of $PM_{2.5}$ and PM_c on pneumonia. Using WHO's guideline (25 μg/m^3) as reference concentration, about 8.32% (95% CI: 5.90%, 10.86%) of respiratory morbidity (3727, 95% CI: 2642, 4867, in morbidity number) were estimated to be attributed to $PM_{2.5}$, and 0.86% (95% CI: 0.50%, 1.23%) of respiratory morbidity, representing 385 (95% CI: 225, 551) hospital outpatient visits, could be attributed to coarse particulate pollutant. Our study suggests that both fine and coarse particulate pollutants are an important trigger of hospital outpatient visits for respiratory diseases, and account for substantial respiratory morbidity in Dongguan, China.

1. Introduction

Short-term exposure to ambient particulate matter (PM) air pollution has been consistently associated with both occurrence and exacerbation of respiratory diseases, resulting in increased rates of emergency room visits and hospital admissions (Cho et al., 2014; Gleason et al., 2014; Lin et al., 2016c). Most of the previous studies focused on PM pollution with an aerodynamic diameter ≤10 μm (PM_{10}) or ≤ 2.5 μm ($PM_{2.5}$). However, several aspects of the relationship between PM pollution and respiratory diseases have remained unclear, such as the most relevant types of respiratory diseases and the most responsible PM size fractions for the respiratory health effects.

In addition, few studies have estimated the respiratory disease burden associated with high-level exposure to PM pollutants (Lin et al., 2016b). Compared with relative risk or odds ratio, the disease burden may provide additional public health information by directly estimating the proportion and absolute number of diseases due to certain exposure, and they can illustrate more suitable information for estimating potential health benefits from eliminating

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* Corresponding author. Guangdong Provincial Institute of Public Health, Guangdong Provincial Center for Disease Control and Prevention, Guangzhou, 511430 China.

** Corresponding author. Guangdong Provincial Institute of Public Health, Guangdong Provincial Center for Disease Control and Prevention, Guangzhou, 511430 China.

E-mail addresses: mawj@gdiph.org.cn (W. Ma), linhualiang2002@163.com (H. Lin).

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exposures (Li et al., 2016; Lin et al., 2016a).

In the present study, we conducted a time-series analysis to estimate the association between $PM_{2.5}$ and coarse PM pollution (PM_c, particles with an aerodynamic diameter of 2.5–10 μm) and hospital outpatient visits for total respiratory diseases, chronic obstructive pulmonary disease (COPD), asthma and pneumonia in Dongguan, a subtropical city in South China; we further estimated the morbidity burden attributable to exposures to $PM_{2.5}$ and PM_c.

2. Methods

2.1. Morbidity data

Data on hospital outpatient visits were obtained from the Dongguan Fifth Hospital located in the southwest of the city, which is one of the highest level hospitals in Dongguan. According to the diseases coding of the 10th revision of the International Classification of Diseases (ICD-10), hospital outpatient visits due to overall respiratory diseases (J00-J99), COPD (J40-J44), asthma (J45-J46), and pneumonia (J12-J18) were obtained between January 19th, 2013 and December 31st, 2015.

2.2. Air pollution and weather variables

Air pollutants, including PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3), were monitored by Dongguan Environmental Monitoring Center and their daily (24-h) concentrations were available. The average of five fixed air monitoring stations was used as the daily concentrations for each air pollutant. We estimated the concentrations of PM_c by subtracting $PM_{2.5}$ from PM_{10} (Lin et al., 2016d). All measurements of the ambient air pollutants were operated according to the China National Quality Control ((HJ/T 193-2005) and (GB3095-2012)).

To adjust for the effect of weather factors on hospital visits, we obtained daily meteorological data (daily mean temperature (°C) and relative humidity (%)) from the China National Weather Data Sharing System (http://cdc.cma.gov.cn/home.do), which is publicly accessible. Weather data were measured by a fixed-site station located in central Dongguan City.

2.3. Statistical analyses

We examined the short-term association between daily PM pollutants ($PM_{2.5}$ and PM_c) and respiratory morbidity using generalized additive models (GAM). A quasi-Poisson link was applied to account for the over-dispersion of daily morbidity. In the model, we controlled for public holidays (PH) and day of the week (DOW) using categorical variables. We also adjusted for seasonal patterns, long-term trend, temperature, and relative humidity using penalized smoothing splines due to their non-linear association with health (Tian et al., 2013). The model specification, a priori, and the degree of freedom (df) for the smoothers were selected according to some previous studies (Tian et al., 2013, 2016). Specifically, we applied 6 df per year for temporal trends to filter out the information at time scales that were longer than two months, a df of 6 for mean temperature of the current day ($Temp_0$) and moving average of previous 3 days ($Temp_{1-3}$) to account, and a df of 3 for the same day's relative humidity ($Humidity_0$). The model is shown as follows:

$$\begin{aligned}\log[E(Yt)] = \beta{*}PM + s(t, df = 6/year) + s(Temp_0, df = 6) \\ + s(Temp_{1-3}, df \\ = 6) + s(Humidity_0, df = 3) + \beta_1{*}DOW + \beta_2{*}PH + \alpha\end{aligned}$$

where $E(Y_t)$ is the expected daily morbidity count on day t, s() indicates a smoother based on penalized smoothing splines, t represents temporal trend, which was used to adjust for long-term trend and seasonality, df is the degree of freedom, PH is a binary variable for the public holiday, β is the regression coefficient, and α is the model intercept.

We examined the associations with different lag structures from the current day (lag_0) up to 3 days before (lag_3), as well as multiple-day lags (moving averages for the current day and the previous 1, 2 and 3 days: lag_{01}, lag_{02}, and lag_{03}).

Sensitivity analyses were performed by changing the df of long-term and seasonal trends (5, 7 and 8 df/year) and of meteorological factors. We also controlled for various gaseous air pollutants (SO_2, NO_2, and O_3) in two-pollutant models. We presented the results of lag days with the largest effect estimate as the percentage change in daily morbidity for each interquartile range (IQR) increase of daily PM concentrations. We also reported the associations using a 10-$\mu g/m^3$ increase.

We further estimated the morbidity burden attributable to short-term exposure to PM pollutants (Lin et al., 2016a). Two metrics, population attributable fraction (PAF) and attributable morbidity (AM), were applied (Zhu et al., 2013). The concentration standard/guideline for $PM_{2.5}$ set by the Chinese National Ambient Air Quality Standards (Dong et al., 2013) and the Air Quality Guidelines by the World Health Organization (WHO) (World Health Organization, 2006) were used as the reference concentrations. PM_c was not regulated by the standards/guidelines. The difference between the standard concentrations of PM_{10} and $PM_{2.5}$ was calculated and utilized as the reference concentration for PM_c. Two reference concentrations were thus used for $PM_{2.5}$ (75 $\mu g/m^3$ according to China's standard, 25 $\mu g/m^3$ according to the WHO's guideline) and PM_c (75μg/m according to China's standard, 25 $\mu g/m^3$ according to the WHO's guideline). PAF and AM were calculated based on the concentration-response relationship obtained in the above analyses. The equations were shown below:

$$AM = \text{baseline morbidity} * [\exp(\beta{*}\Delta PC) - 1]$$

$$\begin{aligned}PAF = \text{baseline morbidity} * [\exp(\beta{*}\,\Delta PC) - 1] \\ \times /\text{overall morbidity}\end{aligned}$$

where PAF is the population attributable fraction of respiratory morbidity; AM is the attributable respiratory morbidity due to exposures to PM pollutants above the reference concentration; baseline morbidity is the average daily morbidity when PM pollution levels were at reference concentrations; β is the coefficient of the PM-morbidity association, we used the effect at lag_{03} in this study; $\triangle PC$ is the concentration difference between the observed PM concentration and the reference concentration; and reference concentration is the air quality standard of China (75 $\mu g/m^3$) and WHO's guideline (25 $\mu g/m^3$). Overall morbidity is the overall morbidity count.

All analyses were performed using R (version 2.13.0; R Foundation for Statistical Computing, Vienna, Austria) with the “mgcv” package. All statistical tests were two-sided, and values of $p < 0.05$ were considered as statistically significant.

3. Results

During the study period, a total of 44,801 hospital outpatients for respiratory diseases were recorded in the study population, among which 13,170 COPD, 9062 asthma, and 2719 pneumonia cases were observed. Daily average respiratory hospital outpatient visits were 42, including 12 COPD, 8 asthma, and 3 pneumonia cases.