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Acute effects of ambient particulate matter pollution on hospital admissions for mental and behavioral disorders: A time-series study in Shijiazhuang, China

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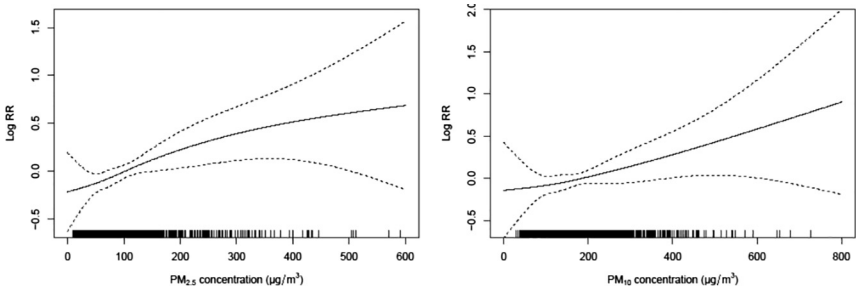
HIGHLIGHTS

- Limited evidence on association between particulate matter and mental and behavioral disorders in developing countries.
- Increased risk of hospital admissions due to mental and behavioral disorders associated with $PM_{2.5}$ and PM_{10}.
- Effect of particulate matter on hospitalizations of mental and behavioral disorders were stronger in male and elderly.
- Generally stronger association of $PM_{2.5}$ occurred in the cool season.

GRAPHICAL ABSTRACT



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ABSTRACT

Until now, few epidemiological studies have focused on the association between ambient particulate matter pollution and mental and behavioral disorders, especially in developing countries. Thus, a time-series study on the short-term association between both fine and inhalable particles ($PM_{2.5}$ and PM_{10}) and daily hospital admissions for mental and behavioral disorders in Shijiazhuang, China was conducted, from 2014 to 2016. An over-dispersed, generalized additive model was used to analyze the associations after controlling for time trend, weather conditions, day of the week, and holidays. In addition, the modification effects of age, sex, and season were estimated. A total of 9156 cases of hospital admissions for mental and behavioral disorders were identified. A 10 μg/m^3 increase in a 3-day average concentration (lag02) of $PM_{2.5}$ and PM_{10} correspond to an increase of 0.48% (95% confidence interval (CI): 0.18–0.79%) and 0.32% (95% CI: 0.03–0.62%) in daily hospital admission for mental and behavioral disorders, respectively. We found stronger associations of $PM_{2.5}$ and PM_{10} with mental and behavioral disorders in male and elder individuals (≥45 years) than in female and younger individuals (<45 years). Further, results indicated a generally stronger association of $PM_{2.5}$ with mental and behavioral disorders in the cool season than in the warm season. This research found a significant association between ambient $PM_{2.5}$ and PM_{10} and hospital admission for mental and behavioral disorders in Shijiazhuang, China.

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1. Introduction

Air pollution, especially particulate matter pollution, is currently the world's largest environmental health risk (Di et al., 2017a; Di et al., 2017b; Landrigan, 2017). As the largest developing country, China is experiencing one of the worst air pollution problems in the world. The Beijing-Tianjin-Hebei region, located in the north part of the North China Plain, is one of the most influential districts. The residents here have experienced several severe and persistent air pollution events every winter since 2013. Many epidemiological studies have found that exposure to $PM_{2.5}$ and PM_{10} is associated with increased risk of mortality and morbidity, even at low and general levels (Pope 3rd et al., 2017; Zhang, 2017). It was estimated that 4.2 million people died globally as a result of $PM_{2.5}$ exposures in 2015 (Cohen et al., 2017).

Previous studies identified that mental diseases may be influenced by genetic (Robinson et al., 2016), education (Ananat et al., 2017), socio-economic (Fazel et al., 2014) and lifestyle factors (Phillips, 2017). More recently, there has been increasing evidence that supports the link between particulate matter pollution and adverse mental or neurological outcomes. For example, animal experiments have found that particulate matter can be transferred from the upper respiratory tract to the brain, leading to brain inflammation, changes in brain activity and pathological function, decreases in neurocognitive abilities, and eventually, mental and behavioral disorders (Calderon-Garciduenas et al., 2010; Calderon-Garciduenas et al., 2004; Xu et al., 2016). Until now, only a small number of epidemiological studies have explored the association between particulate matter pollution and mental and behavioral disorders (Gao et al., 2017; Kioumourtzoglou et al., 2017; Lim et al., 2012). However, the epidemiological evidence is still insufficient, especially in developing countries.

By the end of 2016, there were 231 million people aged 60 years and above in China. Age related health problems, such as mental and neurological diseases, have received significant attention. However, correlation studies on the relationship between air pollution and mental health in developing countries are limited and inconsistent. Furthermore, Shijiazhuang is one of the most polluted cities in China; however, no studies have previously evaluate this association in this region. We thus conducted a time-series study to investigate the impact and explore the exposure-response curves of particulate matter ($PM_{2.5}$ and PM_{10}) on hospital admission for mental and behavioral disorders.

2. Materials and methods

2.1. Data collection

Shijiazhuang is the capital of Hebei province and is situated in the center of Jing-Jin-Ji region. In 2015, the four traditional urban districts (469 km^2) of this city had a permanent population of 2.19 million. Shijiazhuang has a typical temperate monsoon climate. Summers are wet with high temperatures and high humidity, while winters are cold and dry. In this city, central heating is provided from November 15th through March 15th, and millions of kilograms of coal are burned for heating. Thus, air pollution is generally more frequent and severe during this period than other months.

2.1.1. Health data

Daily hospital admissions for mental and behavioral disorders were collected from the Shijiazhuang eighth hospital, which is the only mental disease specialist hospital in Shijiazhuang. Computerized records of daily hospital admissions are available. Daily number of hospital admissions for mental and behavioral disorders during the study period (January 1, 2014 to December 31, 2016) was abstracted from the hospital information system. Mental and behavioral disorders were defined according to the tenth version of the International Classification of Diseases (ICD-10, WHO, 1994), with codes F01–F99.

2.1.2. Air pollution and meteorological data

Daily air pollution data including $PM_{2.5}$, PM_{10} and other gaseous pollutants were obtained from the website of the Chinese Ministry of Environmental Protection (http://106.37.208.233:20035/). The daily average air pollutant concentrations were determined using the 7 fixed stations in the traditional urban area of Shijiazhuang. These stations are mandated to be located away from major roads, industrial source, buildings, or residential source of emission from the burning of coal, oil, or waste; thus, these monitoring results could reflect the urban air pollution level in the city rather than local sources.

Daily meteorological data, including daily mean temperature and relative humidity, were collected from the China Meteorological Data Sharing Service System.

2.2. Statistical analyses

A time-series regression was applied to examine the acute effect of particulate matter ($PM_{2.5}$ and PM_{10}) on hospital admission due to mental and behavioral disorders because it can control for both time-invariant and time-varying confounders. An over-dispersed generalized additive model (GAM) was applied to analyze the association between $PM_{2.5}$, PM_{10}, and daily hospital admissions for mental and behavioral disorders, as daily hospital admissions typically followed a quasi-Poisson distribution. Several covariates were introduced to control for potential confounding effects: (1) a natural cubic regression smooth function of calendar time with 7 degrees of freedom (*df*) per year to exclude unmeasured long-term and seasonal trends longer than two months (Yang et al., 2014); (2) natural smooth functions of the mean temperature (6, *df*) and relative humidity (3, *df*) in order to control for the nonlinear confounding effects of weather conditions (Liu et al., 2017); and (3) indicator variables for "day of the week" and public holidays. The main model is described as follow: $\log E(Yt) = \beta Zt + ns(time, df) + ns(temperature, 6) + ns(humidity, 3) + DOW + intercept$, where E(Yt) represents the expected number of hospital admissions for mental and behavioral disorders at day t; β represents the log-related rate of mental and behavioral disorders admission rate associated with a unit increase of particulate matter pollutants; Zt represents the pollutant concentrations at day t; DOW is a dummy variable for the day of the week; and ns indicates natural cubic regression smooth function (Dai et al., 2015).

After the basic model was established, we further introduced both single-day lags from 0 to 7 and moving average exposure of multiple days, including lag0–1, 0–2, 0–3, 0–4, 0–5, 0–6. The exposure-response relationship curves between $PM_{2.5}$, PM_{10} and hospital admissions for mental and behavioral disorders were plotted by adding a natural spline function with 3 *df* in the above model.

In order to check the stability of our model, two sensitivity analyses were conducted. First, we selected alternative *df* with 4–10 per year for the smoothness of time trends. Second, we built two-pollutant models to examine the robustness of the effect estimates after adjusting for co-pollutants.

In addition, three stratification analyses were conducted to explore the potential effect of modification by sex, age (<45 years and ≥45 years) and season (warm: April to September; cool: October to March). We further tested the statistical significance of differences between effect estimates of the strata by calculating the 95% confidence intervals (CI) as $(\hat{Q}_1 - \hat{Q}_2) \pm 1.96\sqrt{(\hat{SE}_1)^2 + (\hat{SE}_2)^2}$, where $\hat{Q}_1$ and $\hat{Q}_2$ are the estimates for two categories, and $\hat{SE}_1$ and $\hat{SE}_2$ are their respective standard errors (Zeka et al., 2006).

The statistical tests were two-sided, and effects of $p < 0.05$ were considered statistically significant. All statistical models were run in R software (version 3.3.3) using the MGCV package. The effects were presented as the percentage of change and 95% CI in daily hospital admission for metal and behavioral disorders per 10 μg/m^3 increase of $PM_{2.5}$ and PM_{10}.