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Ambient air pollution and daily hospital admissions for mental disorders in Shanghai, China

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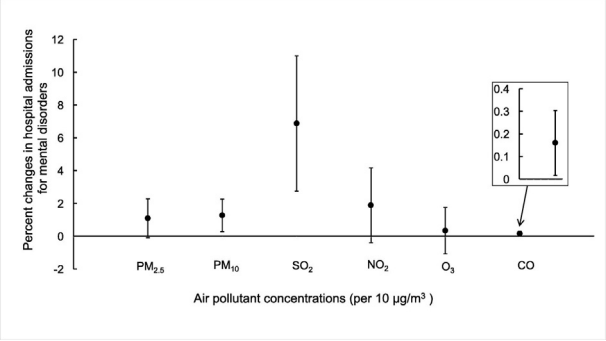
HIGHLIGHTS

- Limited evidence on association between air pollution and mental disorders
- Increased risk of admissions for mental disorders associated with PM_{10}, SO_2, and CO
- Associations of air pollutants were generally stronger in warm period.

GRAPHICAL ABSTRACT



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ABSTRACT

Few studies have investigated the associations between ambient air pollution and mental disorders (MDs), especially in developing countries. We conducted a time-series study to explore the associations between six criteria air pollutants and daily hospital admissions for MDs in Shanghai, China, from 2013 to 2015. The MDs data were derived from the Shanghai Health Insurance System. We used over-dispersed, generalized additive models to estimate the associations after controlling for time trend, weather conditions, day of the week, and holidays. In addition, we evaluated the effect of modification by age, sex, and season. A total of 39,143 cases of hospital admissions for MDs were identified during the study period. A 10-μg/m^3 increase in 2-day, moving-average concentration of inhalable particulate matter, sulfur dioxide (SO_2), and carbon monoxide was significantly associated with increments of 1.27% [95% confidence interval (CI): 0.28%, 2.26%], 6.88% (95% CI, 2.75%, 11.00%), and 0.16% (95% CI: 0.02%, 0.30%) in daily hospital admissions for MDs, respectively. We observed positive but insignificant associations of fine particulate matter, nitrogen dioxide and ozone. The estimated association of SO_2 was relatively robust to the adjustment of simultaneous exposure to other pollutants. We found generally stronger associations of air pollutants with MDs in warm seasons than in cool seasons. There were no significant differences in the associations between different sex and age groups. This study suggested that short-term exposure to air pollution, especially to sulfur dioxide, was associated with increased risk of hospital admissions for MDs in Shanghai, China.

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1. Introduction

Mental disorder (MD) is a syndrome characterized by clinically significant disturbance in an individual's cognition, emotion regulation, or behavior that reflects a dysfunction in the psychological, biological, or developmental processes underlying mental functioning (American Psychiatric Association, 2013). MDs pose a heavy burden on public health, leading to more than one-fifth of years of life lived with disability worldwide (WHO, 2015). Globally, over 350 million people were estimated to be affected by depression; 48 million people were affected by dementia; and 21 million people were affected by schizophrenia and other subtypes of MDs (WHO, 2016).

A full understanding about the risk factors of MDs is of great importance to public health. Previous studies have identified that psychiatric diseases can be induced by genetic (Di Forti et al., 2012; Geschwind and Flint, 2015; Robinson et al., 2016; Whalley, 2016), socio-economic (Fazel et al., 2014; Kawakami et al., 2012), and behavioral risk factors such as smoking (Tobe, 2012). Recently, there is increasing evidence of air pollution hazards on the brain (Block et al., 2012). Until now, only a small fraction of studies has explored air pollution as a novel risk factor for the incidence of MD or its subtypes, such as depressive disorder, completed suicide, panic attacks, etc. (Bakian et al., 2015; Cho et al., 2015; Cho et al., 2014). The associations are biologically plausible, for example, in that environmental factors may cause activation of the immune system, oxidative stress, inflammation, alterations in the concentrations of cerebral neurotransmitters, and eventually lead to mental or behavioral alterations (Deisenhammer, 2003; Kelly, 2003; Xu et al., 2016).

As the largest developing country, China is experiencing one of the worst air pollution problems in the world. Several epidemiological studies in China have revealed that MDs are associated with ambient air pollution, but the evidence is limited and somewhat inconsistent (Gao et al., 2017; Tong et al., 2016). For example, a time-series study in Tianjin, China reported significant associations of psychosis with sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and inhalable particulate matter (PM_{10}) (Tong et al., 2016). However, another study with case-crossover design did not observe significant associations between suicide and PM_{10} or SO_2 (Bakian et al., 2015). Besides, there is a lack of studies evaluating the associations between air pollution and specific subtypes of MDs. Therefore, we conducted this time-series analysis to explore the impacts of air pollution on hospital admissions for total MDs and two sub-categories (manic episode and depressive disorder) in Shanghai, the largest city of China.

2. Methods and materials

2.1. Data collection

Daily hospital admissions for MDs were collected from the database of the Shanghai Health Insurance System, which provides compulsory universal health insurance to most of the residents in Shanghai (The coverage rate was >96% in 2014) (Peng et al., 2017). Computerized records of daily hospital admissions are available for each contracted hospital. We obtained the daily number of hospital admissions for MDs during the study period (January 1, 2013, to December 31, 2015) from this system. MDs were defined according to the 10th version of the International Classification of Diseases, with codes F01–F99. We further considered two categories of MDs: manic episode (ICD: F30) and depressive disorder (ICD: F32–33). The Institutional Review Board at the School of Public Health, Fudan University, approved the study protocol (No. 2014-07-0523) with a waiver of informed consent, because all data were analyzed at aggregate level and no participants were contacted.

2.2. Environmental data

Daily air quality data were obtained from the database of the Shanghai Environmental Monitoring Center. We evaluated six criteria air pollutants: NO_2, SO_2, carbon monoxide (CO), ozone (O_3), PM_{10} and fine particulate matter ($PM_{2.5}$). Air pollutant concentrations were measured at 10 fixed-site monitoring stations in the urban area of Shanghai. According to the Chinese government's rules, these monitors are mandated not to be in the direct vicinity of apparent emission sources (traffic, industry, and boilers, etc.), so that they may represent the general air pollution levels in urban environments. Pollutants were measured using different methods: the method of Tapered Element Oscillating Microbalance for PM_{10} and $PM_{2.5}$, the ultraviolet fluorescence method for SO_2 and O_3, the chemiluminescence method for NO_2, and the infrared absorption method for CO. All these measurements were operated under the China National Quality Control (GB3095-2012). We averaged the daily concentrations of air pollutants from the 10 monitoring stations as the proxy for the general exposure for all populations. We calculated maximum 8-h averages for O_3 and daily 24-h averages for the remaining pollutants. Daily meteorological data, including daily mean temperature and relative humidity, were obtained from a fixed station (Xujiahui) operated by the Shanghai Meteorological Bureau.

2.3. Statistical analysis

Hospital admissions for MDs were linked with air pollutant concentrations by date. We applied a time-series approach to analyze the data, which has the advantage of automatically controlling for time-invariant confounders at population level. Specifically, as daily hospital admissions for MDs approximately followed a *quasi*-Poisson distribution, we used the *overdispersed* generalized additive model (GAM) to analyze the association between daily hospitalizations of MDs and each air pollutant. Consistent with many previous time-series studies in this area, we incorporated several covariates in the main model: (1) a natural smooth spline function of calendar time with 7 degrees of freedom (*df*) per year to control for long-term and seasonal trends longer than two months (Chen et al., 2010; Peng et al., 2006; Zanobetti and Schwartz, 2009); (2) natural smooth functions with 6 *df* for the present-day mean temperature and 3 *df* for the present-day relative humidity to exclude potential nonlinear confounding effects of weather conditions (Chen et al., 2014; Peng et al., 2006); (3) a factor variable for day of the week (DOW) to account for the variation of hospital admissions within a week and (4) a binary dummy variable for public holidays to adjust for the holiday effects (Kan et al., 2008). We used a 2-day moving average of current- and previous-day (lag 01) concentrations of air pollutants in our main model because this lag often produced the largest effect estimate in previous studies (Chen et al., 2012; Kan et al., 2008). To explore the lag patterns in the impacts of air pollution, we further introduced both single-day lags from 0 to 6 and a 7-day moving average of the current and previous 6 days (lag 06), using the same models. The main model is described as follows: $\text{Log } E(Y_t) = Z_t + s\,(\text{day}, df) + s\,(\text{temperature}, df) + s\,(\text{relative humidity}, df) + \text{holiday} + \text{DOW} + \alpha$, where $E\,(Y_t)$ denotes the estimated daily hospital admissions for MDs; Z_t indicates the pollutant concentrations on day t; s denotes a natural spline function; df is the degrees of freedom; and α is the intercept.

We plotted the exposure–response (E–R) relationship curves between 6 air pollutants and hospital admissions for MDs by adding a natural spline function with 3 *df* for each pollutant term in the above main model (Cao et al., 2012).

In addition, we conducted stratification analyses to explore the potential effect of modification by age (≤44, 45–64, and ≥65), sex, and season (cool: October to March; warm: April to September). We further evaluated the statistical significance for the differences in estimates