European Psychiatry 44 (2017) 68–75

Contents lists available at ScienceDirect

European Psychiatry

journal homepage: http://www.europsy-journal.com

Original article

Particulate matter air pollution associated with hospital admissions for mental disorders: A time-series study in Beijing, China

Q. Gao, Q. Xu, X. Guo, H. Fan, H. Zhu *

School of Public Health, Epidemiology and Health Statistics, Capital Medical University, 10 Xitoutiao, Youanmenwai Street, Beijing, China

ARTICLE INFO

Article history:
Received 18 December 2016
Received in revised form 31 January 2017
Accepted 6 February 2017
Available online 7 April 2017

Keywords:
Particulate matter
Mental disorders
Time-series study
Hospital admission
China

1. Introduction

Air pollution is the world's largest single environmental health risk now [1]. It was estimated that 7 millions people died as a result of air pollution exposure in 2012 globally [2]. In the world, 92% of the population lives in places where the levels of air quality exceed the limits of WHO [1]. According to the reactions to variations in their meteorological surroundings in a short time, people can be mainly divided into two groups: weather-resistant and weather-sensitive [3,4]. Previous studies from the West reported weather-sensitive people accounted for over 30% of the whole population [4,5]. When single or composite meteorological factors such as concentration of particulate matter, temperature, atmospheric pressure and humidity acted on these persons, a wide variety of pathological symptoms or functional disorders may occur [3,4,6–9].

The pathophysiological mechanisms of weather on human being are still not clear, and might differ considerably between disorders [10]. There is increasing evidence of air pollution hazards on the brain [11]. Usually, the nervous system responds first to the environmental variations, and the most common weather-triggered biological reactions often displayed a psychological, emotional or behavioral character [3]. Biophysical and meteorological factors may cause changes in the concentrations of cerebral neurotransmitters and eventually lead to mental or behavioral alterations [10,12,13]. Also, air pollution has recently been recognized as a suspected neurodevelopmental toxicant [14].

To date, epidemiological studies on high levels of ambient particulate matter (PM), particularly those with diameters of less than 2.5 μm ($PM_{2.5}$), and a wide range of adverse health outcomes including asthma, lung cancer, respiratory diseases, cardiovascular disease, stroke and premature death have been well documented [15–17]. People with mental disorders are one of the most well-known group effects associated with atmospheric lability [18]. It was reported that individuals with impressionable nervous system were more sensitive to weather changes than others, and the percentage of weather-sensitive subpopulation could reach 85% [5,18].

In China, study about air pollution exposure and mental disorder is scarce. With the changes in concentrations and sources of air pollution over the past decade in China, it is worthwhile to investigate the acute effects of outdoor air pollution on mental disorders. In this study, we conducted a time-series analysis to estimate the acute effects of PM on hospitalizations for mental disorders in Beijing. This study was designed to evaluate our *a priori* hypothesis that hospital admissions for mental disorders would increase with the elevating concentrations of PM. This study may enable the use of the weather forecast for the prediction of an occurrence of some mental responses in people at higher risk under altered atmospheric conditions, and the initiation of attempts to prevent adverse effects.

* Corresponding author.
E-mail address: zhuhuiping@ccmu.edu.cn (H. Zhu).

http://dx.doi.org/10.1016/j.eurpsy.2017.02.492

2. Methods

2.1. Data collection

Data on hospitalizations for mental disorders from January 1st, 2013 to December 31st, 2015 were obtained from Beijing Anding Hospital, which is located in the central part of Beijing, China. Beijing Anding Hospital has been ranked as one of the 5 best psychiatric hospitals in China. Information for each case were collected including date of admission, age, gender, occupation, International Classification of Diseases-10th Revision (ICD-10) discharge diagnosis codes, and primary discharge diagnosis.

For the purpose of this study, mental disorders are used to denote a range of mental and behavioral disorders that fall within the ICD-10, including organic, including symptomatic mental disorders (F00–F09), mental and behavioral disorders due to psychoactive substance use (F10–F19), schizophrenia, schizotypal and delusional disorders (F20–F29), mood (affective) disorders (F30–F39), neurotic, stress-related somatic disorders (F40–F48), behavioral syndromes associated with physiological disturbances and physical factors (F50–F59), disorders of adult personality and behavior (F60–F69), mental retardation (F70–F79), disorders of psychological development (F80–F89), behavioral and emotional disorders with onset usually occurring in childhood and adolescence (F90–F99) and unspecified mental disorder (F99–F99). Our study was reviewed and approved by the Institutional Review Board of Capital Medical University. In this study, de-identified hospital admission data from the Beijing Anding Hospital were analyzed. The re-admissions of inpatients with the same mental disorder within 30 days were excluded.

The hourly concentrations of six air pollutants have been monitored by Beijing Municipal Environmental Monitoring Center (BMEMC) since October 2012, which included particulate matter $\leq 2.5\ \mu m$ in aerodynamic diameter ($PM_{2.5}$), particulate matter $\leq 10\ \mu m$ in aerodynamic diameter (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3). There were 35 monitoring stations dispersed in different districts of Beijing. In this study, data of PM_{10}, $PM_{2.5}$ and other gaseous pollutants in each of monitoring stations from January 2013 to December 2015 in Beijing were obtained from the website platform of BMEMC. Then, 24-h average concentrations of PM_{10} and $PM_{2.5}$ were calculated. We then estimated PMc (particulate matter between 2.5 and $10\ \mu m$ in aerodynamic diameter) concentrations by subtracting daily average concentrations of $PM_{2.5}$ from PM_{10} in the monitoring stations. We also calculated the daily average concentrations of PM_{10}, PM_C, $PM_{2.5}$, NO_2 and SO_2 by averaging the concentrations of all stations to represent the citywide pollution exposure.

The daily mean temperature (°C), relative humidity (%), air pressure (hPa) and sunshine hours (hr) were obtained from the China Meteorological Administration on the corresponding period.

2.2. Statistical analysis

Generalized additive Poisson models were used in this study to examine the association between PM (PM_{10}, PM_C, and $PM_{2.5}$) exposure and hospitalizations for all-cause mental disorders and two specific disorders including schizophrenia and mood disorder. Penalized cubic spline function (ps) was adopted to filter out long-term trends and seasonality in daily hospitalizations, and potential non-linear effects of daily mean temperature, relative humidity and air pressure. The degree of freedom (df) for the time trends and other meteorological variables were selected based on previous studies [19,20]. A df of 7/year was adopted for the time trends and seasonality, and 3 df for the daily mean temperature, relative humidity and air pressure. We also adjusted for the day of the week (DOW), sunshine hours and public holidays (dichotomous variable, 0 indicates no holiday and 1 indicates a holiday) in the models.

A core model was built to remove the long-term trends, seasonality, and adjust for time-varying confounders. Potential autocorrelations in the outcomes were accessed by means of residual plot and partial autocorrelation function (PACF) plot. The PACF of residuals of the core models were smaller than 0.1 for the first two lags, which meant no serial correlation in the residuals and sufficient confounder control [21]. For our data, no clear evidence of autocorrelations was found.

All the models were fitted with different lag structures from the same day up to 5 days before the outcome (single-lag effects from lag0 to lag5). We also used 3-day, 5-day, and 7-day moving averages of the same day and previous 2, 4, and 6 days PM concentrations (lag02, lag04, and lag06) to estimate the overall cumulative effects. Subgroup analyses were performed to examine whether the association differed by age (< 45 years and ≥ 45 years) and gender. The statistical significance of subgroup differences were tested through Z-test. Two-pollutant models that included two pollutants in the same model (PM with SO_2, NO_2, O_3 and CO) were used to explore independent effects of PM on the risk of hospital admissions for mental disorders. A binary variable was created for the season to check if the effects of PM (PM_{10}, PM_C, and $PM_{2.5}$) varied across seasons. The product term was also added between PM concentrations (continuous variable) and the season (binary variable) into the core model [21]. Meanwhile, to evaluate the robustness of our results, we estimated the effects of the 0–6 cumulative concentration of PM (PM_{10}, PM_C, and $PM_{2.5}$) on hospital admissions for mental disorders by changing the degrees of freedom that were used in the smooth function of calendar time (5–10 df/year) in sensitivity analysis.

The results were expressed by using the percentage change (%) in hospital admissions for mental disorders per $10\ \mu g/m^3$ increment of PM concentrations, and their respective 95% confidence intervals (CIs). All of the analyses were performed using the "mgcv" and "nlme" packages in the statistical environment R3.3.0 (Development Core Team, 2016, http://www.r-project.org), and the statistical tests were 2-sided.

3. Results

A total of 13,291 hospital admissions for patients with mental disorders who lived in Beijing were recorded from 1 January 2013 to 31 December 2015 (4529 for schizophrenia and 7290 for mood disorders) (Table 1). There were 46.9% male patients, and 70.6% patients were younger than 45 years old. The mean age of the study subjects was 36.8 ± 14.4 years. The hospital admissions for

Table 1
Characteristics of hospital admissions for mental disorder in Beijing, China from 2013 to 2015.

Variable	*n* (%)
Total number of admissions	13,291 (100.0)
Mental disorders	
Schizophrenia	4529 (34.1)
Mood disorder	7290 (54.8)
Others	1472 (11.1)
Sex	
Male	6234 (46.9)
Female	7057 (53.1)
Age, mean *y* (*SD*)	36.8 (14.4)
< 45	9380 (70.6)
≥ 45	3911 (29.4)
Season	
Cold season	6610 (49.7)
Warm season	6681 (50.3)

SD indicates standard deviation. Cold season: from November to April; Warm season: from May to October.