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Peak expiratory flow, breath rate and blood pressure in adults with changes in particulate matter air pollution during the Beijing Olympics: A panel study

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ABSTRACT

Objectives: This study aims to examine whether changes in short-term exposures to particulate matter are associated with changes in lung function, breath rate, and blood pressure among healthy adults and whether smoking status modifies the association.
Methods: We took advantage of the artificially controlled changes in air pollution levels that occurred during the 2008 Olympic Games in Beijing, China and conducted a panel study of 201 Beijing residents. Data were collected before, during, and after the Olympics, respectively. Linear mixed-effect models and generalized estimating equation models were used to compare measurements of peak expiratory flow, breath rate and blood pressure across three time points.
Results: The mean values of peak expiratory flow were 346.0 L/min, 399.3 L/min, and 364.1 L/min over the three study periods. Peak expiratory flow levels increased in 78% of the participants when comparing the during- with pre- Olympics time points, while peak expiratory flow levels decreased in 80% of participants for the post- and during-Olympic periods comparison. In subgroup analyses comparing the during-Olympic to pre-Olympic time points, we found a larger percentage change in peak expiratory flow (+17%) among female, younger and non-smoking participants than among male, elderly and smoking participants (+12%). The percentage of participants with a fast breath rate (>20/min) changed from 9.7% to 4.9% to 30.1% among females, and from 7.9% to 2.6% to 27.3% among males over the three time points. The changes in blood pressure over the three study periods were not very clear, although there is an increase in diastolic pressure and a decrease in pulse pressure among males during the games.
Conclusions: The results suggest that exposure to different air pollution levels has significant effects on respiratory function. Smoking, age and gender appear to modify participants' biological response to changes in air quality.

1. Introduction

Exposure to ambient air pollution has been linked to various health effects including impaired cardiopulmonary function, respiratory and cardiovascular diseases, cancers, and all-cause mortality (Boffetta, 2006; Franchini and Mannucci, 2007; Mannino and Buist, 2007). Air-borne particulate matter (PM) is a complex mixture of solid and liquid particles of various sizes and compositions, including polycyclic aromatic hydrocarbons (PAH), elemental carbon, organic carbon compounds, transition metals and reactive components. Particulate matter, the air pollution 'cocktail', is believed to be responsible for many air pollution-induced adverse health effects. Although the risk to one individual at any single time point is small, given the high prevalence of

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exposure, particulate matter air pollution has large global public health implications, and ranks as the 13th leading cause of mortality (Brook, 2008). Ambient particulate matter accounts for about 95% of the total air pollution-related damage cost (Pervin et al., 2008).

Short-term exposure to high levels of air pollution exacerbates pre-existing illness and increases mortality among those suffering from various serious chronic diseases. However, it is not clear whether reducing exposure has measurable physiological effects on lung function, breath rate and blood pressure in healthy adults. Peak expiratory flow is defined as the maximum flow generated during expiration, performed with maximal force and started after a full inspiration. It has been used as one of the most direct measurements of lung function, especially in the treatment of asthma. Exposure to a high concentration of air pollution has been linked to the changes in peak expiratory flow, especially among asthma patients (Qian et al., 2009; Hong et al., 2010; Ma et al., 2008; Peters et al., 1996; Pope et al., 1991; Romieu et al., 1996; Wiwatanadate and Liwsrisakun, 2011; Wiwatanadate and Trakultivakorn, 2010; Yamazaki et al., 2011), chronic obstructive pulmonary disease patients (Dusseldorp et al., 1995), children (Pope and Dockery, 1992), (Hoek et al., 1993; Kasamatsu et al., 2006; Mengersen et al., 2011; Nordling et al., 2008; Roemer et al., 1993) and the elderly (Lee et al., 2007). Studies have suggested that air pollution is linked to cardiovascular events, frequent hospitalizations, exacerbation of preexisting cardiac diseases and cardiac related mortality (Franchini and Mannucci, 2012; Hoek et al., 2001). However, evidence linking air pollution with pre-clinical perturbations has been limited among healthy adults. Systemic inflammation has been hypothesized as one of the major signaling mediators linking particulate matter exposure with various adverse outcomes (Calderon-Garciduenas et al., 2008; Diaz-Sanchez, 2000; Seagrave, 2008; Swiston et al., 2008). High levels of particulate matter are related to upregulated inflammatory levels in both in vitro and in vivo studies (Diaz-Sanchez, 2000; Watterson et al., 2007). In addition, although most previous research has studied the effect of air pollution among non-smokers, because it has been believed that smoking plays an overwhelming role in the respiratory function, it is important to see if air pollution has any effect on these already effected individuals. It is of scientific and public health interest to understand whether ambient air pollution exposure will equally affect smokers and nonsmokers.

Beijing, China, has high levels of air pollution due to rapid industrial expansion and the increased number of automobiles on the road. Beijing's annual level of PM_{10} (particulate matter less than 10 μm in diameter) exceeds 150 $\mu g/m^3$, and is ranked the sixth highest among the monitored cities in Chen et al., 2008. Studies have also reported high concentrations of polycyclic aromatic hydrocarbons, ranging from 28.53 to 362.15 ng/m^3, particularly during winter months (Zhao et al., 2010). The Chinese government took steps during the Beijing Olympics and Paralympics to reduce air pollution and particulate matter levels in order to provide all athletes and guests with a cleaner atmospheric environment. Factories were temporarily closed across a large geographic area and vehicle exhaust emissions were reduced by preventing half of Beijing's 3.3 million cars from being driven on any given day. Consequently, the city's ambient air quality dramatically improved during the Olympics and particulate matter decreased to half of the pre-Olympic levels. After cessation of the control measures, particulate matter returned to pre-Olympic levels. These circumstances created a natural experiment with bi-directional change in particulate matter levels, allowing us to observe short-term biological responses to both decreases and increases in air pollution, and may be informative regarding the mechanisms potentiating long-term effect of exposure to particulate matter.

2. Materials and methods

2.1. Study design

Taking advantage of the changes in air pollution levels that occurred during the 2008 Beijing Olympic Games, we designed and conducted a panel study in which we enrolled a cohort of 201 participants residing in Beijing, China. We conducted in-person structured interviews with all subjects during their three clinic visits before (Baseline) and during (1st follow-up) and after (2nd follow-up) the Olympics that coincided with the changes in air pollution levels in Beijing.

2.2. Study population

Subject recruitment: All subjects enrolled in the study lived in a community in the Haidian district. Using the community's health registration system, 260 subjects were randomly selected from a roster of potential participants identified by the community health service center. Research personnel contacted potential participants by phone, and described the study including the voluntary nature of participation in the proposed research project. After receiving detailed information, those who agreed to participate were then asked to schedule three clinical visits and interviews. Prior to the initiation of the field investigation, all participants completed a signed consent process that was approved by Institutional Review Boards at the University at Buffalo and Peking University, China.

Participant selection criteria: Participants were females and males between the ages of 20 and 65 years. Those older than 65 years were excluded because of potential pre-existing medical conditions. Participants were restricted to Han (ethnic) Chinese residing in the Haidian district for at least 1 year (i.e. since August 2007). Participants with a prior medical history of cancer, serious immunological or chronic respiratory diseases were excluded. Participants were not excluded based on their smoking status.

2.3. Clinical visits

The official period for the Olympic and Paralympics was between August 8, 2008, and September 17, 2008. We conducted a series of three clinical visits: one baseline (prior to pollution control measures) and two follow-up visits during and after the Olympics and Paralympics, respectively. Each visit included an in-person interview and physical examination.

2.4. Data collection

2.4.1. General information

Questionnaires were administered by the trained interviewers to all participants during each interview. Two different questionnaires were designed for the baseline and follow-up interviews, respectively. The baseline questionnaire included questions regarding residential address, tobacco use, alcohol use, tea drinking, dietary habits, occupational history, medical history, frequency of stir/deep frying food per day and usage of ventilation in their kitchen, recent incidence of cold and other respiratory diseases, and recent subjective feeling about outdoor air pollution and related symptoms. The follow-up questionnaire focused on questions regarding subjects' change in residential location, lifestyle, occupation, physical condition, and disease symptoms since the previous interview.

2.4.2. Clinical visits were conducted at the district's community health service center

All participants arrived at the center before 8 a.m. on the day of their interview. At each visit, a standard physical examination was conducted by physicians and trained nurses. All results were recorded, and all participants received a copy of the report at the end of examinations. The physical examination included the following: (1) basic measurements: height (cm), weight (kg), body temperature (°C) and blood pressure (mmHg). For the blood pressure measurement, a standard protocol was followed by the research staff throughout the three study periods. All participants were required to sit for at least five minutes to rest before the measurements. During the measurements, they were seated in a chair with their backs being supported, feet flat on the floor and their arms being supported at the heart level. (2) pulmonary function: respiration rate (breath/min) and peak expiratory flow (PEF). Peak expiratory flow was measured by a pre-calibrated peak flow meter. To ensure that the maneuvers were performed correctly, a trained nurse supervised each participant. In total, three correct maneuvers were performed. For each maneuver, the subject waited for at least 10s between blows. If the two largest values differed by greater than 40 L/min, participants performed two extra maneuvers. The highest value of the three maneuvers was recorded as the peak expiratory flow for this person.

2.4.3. Particulate matter air pollution

Air pollution data were collected during the study period, including measurement of instantaneous and continuous particulate matter concentration in the