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Associations of gestational and early life exposures to ambient air pollution with childhood respiratory diseases in Shanghai, China: A retrospective cohort study

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ABSTRACT

Background: Associations of ambient air pollutants with respiratory health are inconsistent.
Objectives: We analyzed the associations of gestational and early life exposures to air pollutants with doctor-diagnosed asthma, allergic rhinitis, and pneumonia in children.
Methods: We selected 3358 preschool children who did not alter residences after birth from a cross-sectional study in 2011–2012 in Shanghai, China. Parents reported children's respiratory health history, home environment, and family lifestyle behaviors. We collected daily concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter with an aerodynamic diameter ≤10 μm (PM_{10}) during the child's total lifetime (2006–2012) for each district where the children lived. We analyzed the associations using logistic regression models.
Results: After adjusting for covariates and the other studied pollutants, we found that exposure to NO_2 (increment of 20 μg/m^3) during the first year of life was significantly associated with asthma [odds ratio (OR) = 1.77; 95% confidence interval (CI): 1.29–2.43] and allergic rhinitis (OR = 1.67; 95% CI: 1.07–2.61). Exposure to NO_2 during gestation, the first two and three years, and over total lifetimewas all consistently associated with increased odds of allergic rhinitis. Quartiles of NO_2 concentration during different exposure periods showed a slight dose–response relationship with the studied diseases. These diseases had significant associations with pollutant mixtures that included NO_2, but had no significant association with exposures to SO_2 and PM_{10} individually or in mixtures.
Conclusions: Gestational and early life exposures to ambient NO_2 are risk factors for childhood respiratory diseases.

1. Introduction

Outdoor air pollution in China's large cities has become a topical issue (Zhang et al., 2012; Kan et al., 2012). Meanwhile, prevalences of childhood asthma and allergic diseases in these cities have been rapidly increasing (Huang et al., 2015; Zhang et al., 2013a). Associations between outdoor air pollution and childhood respiratory diseases have been widely studied, but the findings in these studies remain inconsistent (Guarnieri and Balmes, 2014; Laborde et al., 2015).

Specifically, several reviews have concluded that exposures to ambient nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and particulate matter with an aerodynamic diameter ≤10 μm (PM_{10}) independently of each other could exacerbate symptoms in asthmatic patients, and/or induce new-onset of childhood asthma (Brunekreef and Holgate, 2002; Bowatte et al., 2015; D'Amato et al., 2002; Gasana et al., 2012; Guarnieri and Balmes, 2014; Kim et al., 2013; Weinmayr et al., 2010). Gasana et al. (2012) conducted a meta-analysis with nine cohort studies and ten cross-sectional studies published before January 2011, and

Abbreviations: CCHH, China, Children, Homes, Health; CI, confidence interval; CO, carbon monoxide; ISAAC, International Study of Asthma and Allergies in Childhood; NO_2, nitrogen dioxide; NO, nitrogen monoxide; NO_x, nitrogen oxides; OR, odds ratio; PM_{10}, particulate matter with an aerodynamic diameter ≤10 μm; $PM_{2.5}$, particulate matter with an aerodynamic diameter ≤2.5 mm; SO_2, sulphur dioxide.

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concluded that children who lived near or attended schools near high traffic density roads had greater exposure to motor vehicle air pollutants [NO_2, SO_2, PM_{10}, carbon monoxide (CO), nitrogen monoxide (NO), nitrogen oxides (NO_x), ozone (O_3), and particulate matter with an aerodynamic diameter <2.5 mm ($PM_{2.5}$)] and had higher prevalence of childhood asthma and higher incidence of wheeze. Bowatte et al. (2015) searched major databases for peer-reviewed articles from 1960 to March 2014 and summarized birth cohort studies regarding the associations between traffic-related air pollution (PM_{10}, $PM_{2.5}$, black carbon, NO_2, NO, NO_x) exposure in early childhood and subsequent allergic or respiratory outcomes reported at any age. They concluded that early childhood exposure to these pollutants was associated with the development of childhood asthma in children <12 years old, and also found some evidence for the associations of these pollutants with lifetime hay fever (that is, allergic rhinitis).

Moreover, numerous studies have found that short-term exposures (Leitte et al., 2011; Mann et al., 2010; Weinmayr et al., 2010) and acute exposures (Cai et al., 2014; Ezratty et al., 2014; Spira-Cohen et al., 2011; Sarnat et al., 2012) to outdoor air pollution may perhaps increase the risk of wheezing among asthmatic children. Long-term exposure to ambient air pollutants may induce new-onset of childhood asthma and/or allergic rhinitis, and/or respiratory infections (Brauer et al., 2002; Brunst et al., 2015; Delfino et al., 2014; Eckel et al., 2011; Gauderman et al., 2005; Gehring et al., 2015; Guo et al., 1999; Jerrett et al., 2008; Liu et al., 2014a; Lu et al., 2013; MacIntyre et al., 2014; McConnell et al., 2010; Mustapha et al., 2011; Wilhelm et al., 2008). Several studies have also found that exposure to ambient air pollution during gestation and the first year of life was related to developing childhood asthma (Clark et al., 2010; Deng et al., 2015) or lower respiratory tract infections in infants (Aguilera et al., 2013). Several studies have found that various mixtures of ambient air pollutants are more strongly associated with childhood asthma and allergic rhinitis than are the single pollutants SO_2, NO_2, and PM_{10} (Deng et al., 2015; Lu et al., 2013; Parker et al., 2009; Wilhelm et al., 2008). A recent study reported that exposure to high level of SO_2 and NO_2 independently of each other or to their mixtures during both gestation and the first year of life significantly increased the risk of childhood asthma among 3–6 year-old children from Changsha, China (Deng et al., 2015).

However, studies in Norway (Oftedal et al., 2009) and in the United States (Parker et al., 2009) found that long-term exposure to NO_2 (median concentration: 25.0–40.5 μg/m^3 for different exposure years of life in Norway and 17.8 μg/m^3 in the United States) were not significantly associated with new-onset asthma or its related symptoms. A global-scale study using satellite-based estimates reported no positive associations between ambient air pollution and childhood asthma prevalence at the community level (Anderson et al., 2012). A multi-center study in Europe (ESCAPE) also found no significant association between outdoor air pollution and childhood asthma prevalence (Mölter et al., 2015) or adult asthma prevalence (Jacquemin et al., 2015).

Few studies of ambient air pollution and childhood respiratory health have been conducted in China (Cai et al., 2014; Deng et al., 2015; Liu et al., 2014a; Lu et al., 2013; Zhang et al., 2002; Zhao et al., 2008). To our best knowledge, there are no studies simultaneously investigating and comparing the associations between gestational and early life exposures to ambient air pollutants in different terms and childhood respiratory diseases in China. Therefore, in the present study, using data from a cross-sectional survey in the China, Children, Homes, Health (CCHH) study in Shanghai city (Hu et al., 2014; Huang et al., 2015), and daily data for ambient air pollutants provided by Shanghai Environmental Monitoring Center (SEMC), we investigated the associations between mean concentrations of SO_2, NO_2, and PM_{10} individually and in various mixtures during different periods of life from gestation to the survey day, and lifetime-ever prevalence of doctor-diagnosed asthma, allergic rhinitis and pneumonia among preschool children. We hypothesized that exposures to these air pollutants individually and their mixtures in different periods of life are associated with the studied diseases.

2. Materials and methods

2.1. CCHH questionnaire

Phase-one of the CCHH study was a national multicenter cross-sectional study of home environments and childhood asthma, allergies, and airway diseases (Zhang et al., 2013a). In Shanghai, we multi-stage hierarchically sampled 17,898 children in 72 kindergartens from five districts, and distributed a standard questionnaire to their parents or guardians at teacher–parent meetings or by post to the children's teachers, who then distributed the questionnaires along with explanatory guidance to the parents or guardians. In the questionnaire, we translated the questions for children's health from the International Study of Asthma and Allergies in Childhood (ISAAC) (Asher et al., 1995) to Chinese. In addition, we modified and translated questions about home environment and lifestyle behaviors from the Dampness in Building and Health (DBH) study in Sweden (Bornehag et al., 2004) to Chinese. The ethical committee for the School of Public Health, Fudan University in Shanghai approved the questionnaire and proposal for the CCHH study. More information on the Shanghai CCHH study has been provided in a previous article (Huang et al., 2015).

Questions about asthma, allergic rhinitis, and pneumonia were as follows: 1) doctor-diagnosed asthma, ever: Has your child ever been diagnosed with asthma by a doctor; 2) doctor-diagnosed allergic rhinitis, ever: Has your child been diagnosed with hay fever or allergic rhinitis by a doctor; and 3) doctor-diagnosed pneumonia, ever: Has your child ever been diagnosed with pneumonia by a doctor. Children were defined as having the disease when their questionnaires were answered “Yes” to the corresponding questions.

2.2. Studied children

We selected 3358 four to six year-old children who were born between 2006 and 2008 in Shanghai and for whom we had birthdate, and who had not changed residence since gestation. Supplemental material Fig.A.1 shows the selection process for the studied sample. These 3358 children were from 44 kindergartens distributed among three districts of Shanghai city (Fig. 1). Jing-An district is in the center of the city and has high residential and vehicular road density; Bao-Shan district is a suburb near downtown with a vast iron and steel mill; and Feng-Xian district is a suburb far from Shanghai center city, has low residential density and population and no large industrial factories. Since these studied subjects were from specific districts and had specific exposures, we defined this study as a retrospective cohort study.

2.3. Ambient air pollution

For each of the 18 districts in Shanghai city, the Shanghai Environmental Monitoring Center (SEMC) provided daily (24 h) mean concentrations of SO_2, NO_2, and PM_{10}, from January 1, 2006 to April 30, 2012. Daily measurements were made of outdoor SO_2 (ultraviolet fluorescence), NO_2 (chemi-luminescence methods) and PM_{10} (tapered element oscillating microbalance) in each district. We classified exposure periods as gestation, first year, first two years, first three years, and total years since birth (from birth day to the surveyed day). For each child, we calculated period-averaged concentrations of daily SO_2, NO_2, and PM_{10} during these periods in the specific district where the child's residence was located to represent exposure levels to ambient air pollutants during various periods. The period-mean concentration was the arithmetically-averaged value of cumulative daily measurements divided by number of days in the time segments. For example, if a child was born in January 1, 2006 and his residence was located in Jing-An district, we considered the averaged value of daily SO_2