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Critical Literature Review

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A review of the association between air pollutant exposure and allergic diseases in children

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ABSTRACT

We reviewed the results of previous studies that investigated the association between allergic symptoms in children and exposure to the major air pollutants, here identified as nitrogen dioxide (NO_2), ozone (O_3), particulate matter ($PM_{2.5}$ and PM_{10}), volatile organic compounds (VOCs), sulfur dioxide (SO_2), soot, and carbon monoxide (CO), in terms of the odds ratios reported. We also reviewed a common procedure used in previous studies for building a whole study design based on application of an observational research method and various analysis models. Most previous studies reported odds ratios above unity and found a positive association between allergic symptoms and exposure to major air pollutants. When the strength of the associations between exposure to air pollutants and allergic disease in children were compared by normalization of the odds ratios, exposure to $PM_{2.5}$ was found to have the strongest association, followed by NO_2, while exposure to PM_{10} was found to have the weakest association.

Keywords: *Air pollutant, indoor air quality, children, allergic diseases, odds ratio*

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1. Introduction

The prevalence of allergic symptoms has been increasing for several decades. Previous studies indicate that occurrence or severity of allergic diseases is associated with the concentration of air pollutants, one of the environmental risk factors. In their assessments of air pollutants' effects on human health, Jones (1999), Franklin (2007), Braback and Forsberg (2009), and Leung et al. (2012) reported that chemical and biological air pollutants in indoor and outdoor air are important factors that affect the morbidity of allergies and asthma. More specifically, Braback and Forsberg (2009) found that previous cohort studies conducted worldwide commonly indicated that air pollutants from traffic exhaust can affect children's respiratory symptoms. Their results were supported by Leung et al. (2012), whose review of research articles indicated an association between exposure to air pollutants and prevalence of allergic diseases in children and adults in Asian countries.

In the modern era, individuals spend more time indoors than outdoors, particularly children, who are well known to spend most of their time in indoor environments (Franklin, 2007). Farrow et al. (1997) found that children in the United Kingdom spend more time (19.3 hours per day, 80.4%) within the home than their mothers or fathers (18.4 and 14.7 hours per day, respectively). Likewise, Wiley et al. (1991) reported that children in California spend about 85% of their time in indoor environments. These findings are troublesome, as children are considered more vulnerable to allergic diseases due to their higher physical activity and inhalation rate per kilogram of body weight than adults, as well as the development of their organ functions (Abelsohn and Stieb, 2011). Therefore, it is important to investigate children's exposure to indoor air pollutants, particularly those that are more likely to influence the prevalence of atopic dermatitis, bronchitic symptoms, wheeze, and asthma. At the same time, outdoor air quality must also be considered, as it influences the indoor air quality through the penetration of outdoor air into the indoor environment and affects children engaging in outdoor activities, such as sports, which they tend to perform more frequently than adults. For these reasons, many researchers have attempted to demonstrate that exposure to both outdoor and indoor air pollutants significantly affects diverse respiratory diseases, allergic symptoms, and asthma in children (e.g., Nicolai, 1999; Shima and Adachi, 2000; Lee et al., 2003; Hulin et al., 2010; Hwang and Lee, 2010).

One major outdoor pollutant is soot, the accumulation of atmospheric carbonaceous material resulting from the incomplete combustion of organic matter that is associated with high–traffic areas (Wolff, 1985). Previous studies (Studnicka et al., 1997; Guo et al., 1999; Fisher et al., 2000; Lee et al., 2008; Morgenstern et al., 2008; Delfino et al., 2009; Kramer et al., 2009; Spira–Cohen et al., 2011) focusing on air quality near traffic–concentrated areas investigated the impact of exposure to soot and other major traffic–related pollutants, such as nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter (PM), and sulfur dioxide (SO_2) on human health, as well as the relationship between traffic density or proximity to main roads, an indicator of degree of traffic–related air pollution and asthma, respiratory illness, and wheeze among children (Wjst et al., 1993; Oosterlee et al., 1996; Schafer et al., 1996; English et al., 1999; Wilkinson et al., 1999; Venn et al., 2001; Zmirou et al., 2004; Loyo–Berrios et al., 2007; Jerrett et al., 2008; Cook et al., 2011). These studies agreed that increase in traffic density and/or residence in close proximity to main roads is associated with increased prevalence of respiratory, allergic, atopic, and/or asthmatic symptoms in children. Besides traffic–related pollutants, volatile organic compounds (VOCs) emitted from building materials and microbial pollutants, such as dust mite and fungi, have been investigated as allergy–inducing factors (Carrer et al., 2001; Huss et al., 2001; Walinder et al., 2001; Beltrani, 2003; Lee et al., 2003; Takigawa et al., 2010).

The main purpose of this review was to summarize the effects of exposure to air pollutants on the prevalence, risk, or severity of asthma and allergic symptoms in children. To do so, the odds ratios reported in previous studies regarding the odds of each major allergic disease associated with exposure to each major air pollutant were compared to identify which pollutants are associated with greater odds of allergic symptoms in children. The common procedures used in previous studies for building an overall study design to assess the effects of exposure to the major air pollutants were also summarized. After Section 1 presents the background of the study, Section 2 describes the research design and methods of exposure assessment. Section 3 then discusses the air pollutants examined in previous studies before Section 4 evaluates the association between exposure to these air pollutants and allergic diseases via analysis of the odds ratio. Based on the findings, Section 5 concludes the study by describing the major findings, and Section 6 provides recommendations regarding future research to improve understanding of the relationship between human health and exposure to air pollutants.

2. Study Design and Exposure Assessment

To identify previous studies investigating the association between allergic diseases and air pollutants, the Science Direct, PubMed, and Google Scholar databases were searched to locate articles examining allergic diseases, including asthma, wheeze, bronchitis, and eczema, in children aged 0 to 18 years.

Review of the articles revealed that a common procedure used to investigate the impact of air pollutants on allergic diseases and respiratory symptoms in children can be divided into the three steps as diagnosis of symptoms, air pollutant measurement, and statistical analysis. In the first step, diagnosis of diseases and symptoms in children is performed via administration of questionnaires or dermatology tests. In the second step, air pollutant concentrations are measured or estimated using a model to investigate the extent of human exposure. In the final step, the effects of exposure to air pollutants on the occurrence of allergic symptoms are statistically analyzed using the data collecting from performing the previous two steps.

In the diagnosis of symptoms, one observational research method, such as cross–sectional study, cohort study, or case–control study, is used. According to Mann (2012), cross–sectional study tests the occurrence of a disease for each individual at a given point in time by administration of a questionnaire, an interview, or a test, and then often determines the prevalence of a certain symptom. Since a cross–sectional study is typically performed once without any follow–up, it is known as a relatively inexpensive and rapid method (Mann, 2012). Cohort study tests the incidence of a disease among a group of people over a specific period by performance of periodic follow–ups. As it allows for observation of temporal sequence events, cohort study may permit identification of causal relationships, which cross–sectional study cannot (Mann, 2012). Case–control study investigates and compares the individuals with and without a certain symptom, which is particularly effective for investigating diseases with a low rate of incidence (Mann, 2012). In selecting samples for studies using these designs, infants, young children, or schoolchildren living in various areas are typically evaluated as possible participants. After selecting the study population, questionnaires, interviews, or tests are administered to the participants or either their parents or guardians to determine the incidence of allergic symptoms and exposure to relevant environmental factors.

As shown in Table 1, cross–sectional study and cohort study have frequently been used among the three different types of study designs in previous studies. To provide better understanding of the cohort study design, Table 2 summarizes the study duration and follow–up frequencies reported in previous studies. As can be observed, the average study duration of cohort studies was approximately 2.4 years and the follow–up frequency was more than 2 times during the study. The major air pollutants tested in previous studies were NO_2, SO_2, ozone (O_3), and PM, including that consisting of particles smaller than 2.5 or 10 µm in diameter. These studies mainly focused on examining allergic diseases in children between approximately 0 to 18 years of age.

Table 1 shows that for the diagnosis of atopic dermatitis, bronchitic symptoms, wheeze, or asthma, most studies examined data (1–h, 8–h, 24–h yearly; 3–year; or 4–year mean data) collected from the nearest monitoring centers to track changes in air pollutant concentrations (e.g., McConnell et al., 1999; Lee et al., 2003; Hwang et al., 2005; Ho et al., 2007; Lee et al., 2008; Lin et al., 2008; Mar and Koenig, 2009). This method can be combined with modeling using a geographic information system (GIS) to predict levels of air pollutants in a specific area. At the same time, many studies conducted stationary measurement at homes, schools, or selected sites using methods for quantifying the concentration of each pollutant (e.g., Shima and Adachi, 2000; Janssen et al., 2003; Rumchev et al., 2004; Zhao et al., 2008). As shown in Table 3, the individual and stationary measurement methods used varied, depending on the pollutants measured. For example, the concentration of soot was often assessed by measurement of the reflectance of $PM_{2.5}$ filters, which is known to be highly correlated with simultaneously measured concentrations of elemental carbon (EC), a major component of soot (Ulrich and Israel, 1992; Kinney et al., 2000). In addition, several studies used a modeling method to estimate the exposure levels in an area where personal and stationary measurements could not be performed (e.g., Mongerstern et al., 2008; Kramer et al., 2009; Spira–Cohen et al., 2011).

After collecting the air pollutant concentration data, the studies subjected them to diverse analysis methods, including two–, three–, multi–stage model analysis; regression model analysis; Cox regression model analysis; or mixed model analysis. By such means of analysis, the odds ratio, the ratio of the probability of occurrence of a symptom or disease occurrence to that of its non–occurrence (Mann, 2003); the hazard ratio; or the relative risk for the association between exposure to an air pollutant and allergic diseases could be determined. In performing the association analysis, various confounding factors, such as age, sex, and race, were considered, as were many pollution sources, such as combustion engines, that produce multiple pollutants simultaneously. As a result, pollutant concentrations tend to be found to be correlated with each other, and synergistic effects among multiple pollutants are often identified. Therefore, the odds ratios reported were often adjusted for various confounding factors and/or concentrations of other pollutants.

3. Main Air Pollutants Associated with Allergic Diseases

3.1. Nitrogen dioxide (NO_2)

Nitrogen dioxide (NO_2) is mainly emitted from combustion sources but can penetrate into indoor environments. As an irritant of the mucosa membrane of the lungs and respiratory track