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Outdoor particulate air pollution and indoor renovation associated with childhood pneumonia in China

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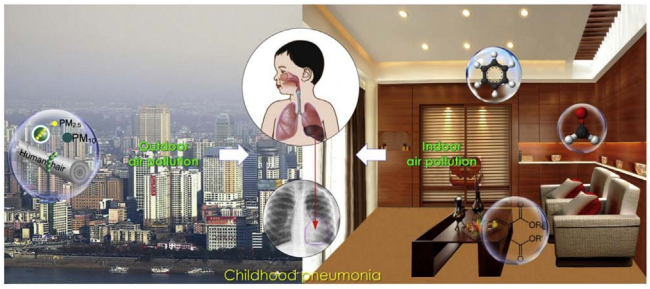
GRAPHICAL ABSTRACT



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ABSTRACT

Background: Pneumonia is a common early-childhood respiratory infection that leads to long-term health impacts, but its risk factors remain unclear.
Objective: To examine the association between early life exposure to both outdoor and indoor air pollution and childhood pneumonia.
Methods: We conducted a retrospective cohort study of 2598 children aged 3–6 years in Changsha, China (2011-2012). Children's life-time prevalence of pneumonia and exposure to indoor air pollution related to home renovation were surveyed by a questionnaire answered by the parents. Children's exposure to outdoor air pollution, including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter with an aerodynamic diameter ≤ 10 μm (PM_{10}), was estimated using the measured concentrations at monitoring stations. Association between childhood pneumonia and exposure to indoor and outdoor air pollution during both prenatal and postnatal periods were examined by using logistic regression model in terms of odds ratio (OR) and 95% confidence interval (CI).
Results: Life-time prevalence of pneumonia in preschool children in Changsha is high, up to 38.6%.We found that childhood pneumonia was associated with postnatal exposure to outdoor particulate air pollutant PM_{10}, adjusted OR (95% CI) = 1.26 (1.00–1.57) for per 6 μg/m^3 increase in the concentration. Pneumonia was also associated with postnatal exposure to indoor renovation, adjusted OR (95% CI) = 1.30 (1.02–1.64) for new furniture and 1.30 (1.00–1.69) for redecoration. Combined exposure to outdoor high PM_{10} and indoor renovation significantly increased the pneumonia risk. Sensitivity analysis indicated that the association was heterogeneous in different subgroups, but stronger in male and younger children.

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Conclusion: High prevalence of childhood pneumonia in China may be associated with postnatal exposure to ambient particulate air pollution and house renovation.

1. Introduction

Pneumonia is one of the most common reasons for hospital admission and the first leading cause of death in children (Liu et al., 2012; Walker et al., 2013). Pneumonia accounted for 15 percent of all under-five deaths and killed 920,000 children in 2015; 99% of deaths occurred in low and middle income countries (Zar et al., 2013). In addition, childhood pneumonia has wide-ranging complications and sequelae in later life, which not only has a crippling effect on child's development and quality of life but also results in heavy economic burden for both family and society (Le et al., 2014; Walker et al., 2013). Most pneumonia are preventable (Bhutta et al., 2013), and therefore there is a critical need to investigate the main risk factors of pneumonia so as to provide more effective preventative strategies.

Childhood clinical pneumonia is a complex disease caused by a combination of host, infection and the environment factors (Rudan et al., 2008). Although host and infection factors strongly influence the risk of pneumonia, environmental factors have been shown to be a significant risk factor for the development of pneumonia (Miao et al., 2017; Zeng et al., 2017). Recent studies have suggested that outdoor air pollution was associated with childhood pneumonia, but mainly focused on the association between short-term exposure and emergency department visits for pneumonia (Fusco et al., 2001; Neupane et al., 2010). The effect of long-term exposure to air pollution on childhood pneumonia is unclear and has never been investigated.

On the other hand, indoor air pollution may have a greater impact than outdoor air pollution because children spend 90% of their time indoors (Nazaroff and Goldstein, 2015; Zhang and Smith, 2003). With the rapid economic growth and urbanization process in China during the past decade, a huge amount of people, particularly the new couples and expectant parents, have moved into new buildings with redecoration and new furniture (Deng et al., 2015b). The new house and house renovation have become a major source of indoor air pollution and their impact on the health of children who was born or will be born is an increasing concern in China (Gao et al., 2014). However, there is a lack of examination for the risk of childhood pneumonia due to indoor air pollution generated by renovation.

Recently, early-life exposure to air pollution has attracted considerable attention, as it influences developmental plasticity and hence leads to later development of a variety of complex diseases (Deng et al. 2016a,b, 2017; Gluckman et al., 2008; Suk et al., 2016). Therefore, our study aims to examine childhood pneumonia risk due to early life exposure to outdoor air pollution and indoor renovation in China during both prenatal and postnatal periods, so as to identify the susceptible windows of exposure and key components of air pollution in the development of pneumonia. Accordingly, we carried out a cohort study in Changsha, a part of nationwide multi-center “China-Children-Homes-Health (CCHH)” study (Zhang et al., 2013).

2. Method

2.1. Study population

We conducted a survey for respiratory disease in children in Changsha during the period from September 2011 to January 2012. The study protocol and questionnaire were described elsewhere (Deng et al., 2015a). We distributed 4988 questionnaires to the children at 36 randomly selected kindergartens. Children were instructed to have the questionnaire completed by parents and to return it to kindergartens within one week. We received 3897 completed questionnaires (78% response rate) but excluded: (1) 745 children in kindergartens with response rate $<$ 50%, as the children are mainly from the rural areas and thus their exposure during pregnancy cannot be estimated; (2) 162 children with low birth weight ($<$ 2.5 kg) or preterm birth ($<$ 37 weeks of gestation) and 10 children with multiple births, as these conditions may confound the effect of air pollution; (3) 80 children younger than 3 and older than 6, because they are too few; (4) 302 children without information about pneumonia. Totally, the 2598 complete data sets were entered into a database.

2.2. Exposure timing windows

Children's exposure was divided into prenatal and postnatal periods. The prenatal exposure referred to the exposure during the entire pregnancy that was defined as from the first month to the last month of pregnancy, and the postnatal exposure was defined as the exposure during the period from the first year to the past year.

2.3. Exposure to ambient air pollution

Ambient air pollution was characterized by three criteria pollutants: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter $\leq$ 10 μm in diameter (PM_{10}). We obtained daily average concentrations of the air pollutants from 7 municipal air quality monitoring stations. Children's daily exposure were estimated by air pollutant concentrations at the kindergartens that were projected from those at the stations by using an inverse distance weight (IDW) method (Deng et al., 2015a). Prenatal exposure was calculated as average of the monthly mean concentrations of PM_{10}, SO_2 and NO_2 during the full gestational months. Postnatal exposure was calculated as the average of the monthly mean concentrations of air pollutants during all months from the first year to the past year.

2.4. Exposure to indoor renovation

Children's exposure to indoor renovation in terms of new furniture and redecoration was assessed by the questionnaire survey. Exposure to new furniture was assessed by the question: “Did you install new furniture in your house (Yes/No/Don't know)?” and if yes, “When did you install the new furniture (During pregnancy/First year of life/After first year of life)?” Exposure to redecoration was assessed by another question:“Did you redecorate your house (Yes/No/Don't know)?” and if yes, “When did you redecorate your house (During pregnancy/First year of life/After first year of life)?”

2.5. Health outcome

The health outcome of the questionnaire, lifetime prevalence of pneumonia, was based on the answer to the question: “Has your child ever been diagnosed with pneumonia?”

2.6. Confounding covariates

Potential confounding variables are also obtained from the questionnaires that include: (1) child-related covariates included sex, age, birth season, breast-feeding, day-care attendance; (2) parent-related covariates included parental atopy and socioeconomic status (SES) indicating by housing size; (3) residential-related covariates included environmental tobacco smoke (ETS), visible mold/damp stains at home, and window condensation in winter. It was identified that these