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Household indoor air quality and its associations with childhood asthma in Shanghai, China: On-site inspected methods and preliminary results

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ABSTRACT

Few studies were conducted for associations of home environment with childhood health by on-site inspection in China. During 2013–2014, we conducted a case-control study with home inspection among 454 children (186 asthma children and 268 non-asthma children) in Shanghai, China. In this paper, we detailedly described the inspected methods and analyzed the preliminarily collected data. Except in winter, most residences meet the national standard for indoor temperature and relative humidity. Most living rooms had ≤ 1000 ppm CO₂, whereas over half of the child's bedrooms had slightly > 1000 ppm CO₂ during night. Most residences had notably lower than 2500 cfu/m³ airborne culturable fungi and ≤ 100 $\mu\text{g}/\text{m}^3$ formaldehyde. More than 70% of the child's bedrooms had ≤ 75 $\mu\text{g}/\text{m}^3$ PM_{2.5} and ≤ 150 $\mu\text{g}/\text{m}^3$ PM₁₀. Indoor and outdoor concentrations of particulate matters had strong linear correlations ($r=0.891\text{--}0.922$; $p\text{-value} < 0.001$). Most differences between cases and controls were not significant with respect to CO₂, culturable fungi, formaldehyde, and particulate matters. Before and after adjusted for potential confounders, indoor averaged concentration of CO₂ and particulate matters generally had negative associations with childhood history of doctor-diagnosed asthma in spring, summer, and autumn. Only in winter, indoor CO₂ concentration was significantly associated with the increased odds of childhood asthma. Our results indicated that air quality among most residences in Shanghai could meet the national standard for indoor air quality in warm seasons; but household air quality and ventilation status in winter should be greatly improved. We suspected that those "unexpected" negative associations could exist due to changes in lifestyle behaviors regarding indoor air quality after the child being diagnosed asthma by a doctor.

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1. Introduction

Previous literatures have consistently suggested that prevalences of childhood asthma among young children were rapidly increased in many developing countries (Asher et al., 2006) and in China (Huang et al., 2015; Zhang et al., 2013a). Populations in China are so big that burden of childhood asthma could be heavier

and heavier if the prevalence continuously increased. Therefore, it is important to find out the potential risk factors for childhood asthma and to provide a practical guidance for its prevention in China.

Because children spend more than 80% of their time in the residence, many studies worldwide have reported that indoor air quality of the residence could play an important role on the children's respiratory health (Brunekreef and Holgate, 2002; Dales et al., 2008; Gordon et al., 2014; Jones, 1999; Sundell, 2004). In China, with the rapid development of both economy and construction technology in the past 30 years, more and more artificial building materials and modern-style furniture have been used in

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the residential building in China (Huang et al., 2015; Zhang et al., 2013a). Indoor air quality of the residence in China perhaps have been greatly changed, and people here started paying more attention to the effect of indoor air quality of the residence on their health than before (Zhang et al., 2013a). With regard to associations of indoor environment and childhood asthma, allergy, and airway diseases, two large-scale questionnaire-based studies were conducted in China: One was Seven Northeast Cities (SNEC) study in Northeast China (Dong et al., 2011), and another was the China, Children, Homes, Health (CCHH) study in more than ten large cities of China (Zhang et al., 2013a). A few studies on indoor air quality of the residence with on-site inspection and measurement were also conducted in China (Lu et al., 2010; Wang et al., 2008, 2010; Wu et al., 2008; Yoshino et al., 2006; Zhang and Smith, 2007; Zhang et al., 2015; Zheng et al., 2011; Zhu et al., 2015). Specifically, in 2008, Lu et al. (2010) conducted an on-site measurement in 100 Shanghai residences and found that the formaldehyde level in summer-autumn was higher than in winter-spring. During spring of 2013, Zhu et al. (2015) inspected indoor pollutants in 10 homes of schoolchildren in Wuhan, China and reported that unhealthy children had higher averaged concentration of carbon dioxide (CO₂) in the living room than health children. In 2006–2007, Wang et al. (2008) inspected indoor air quality in the 120 residences of young schoolchildren in Lanzhou, China during heating and non-heating seasons, and suggested that these residences had worst situation of PM₁₀ when compare to other pollutants and exposures to indoor air pollutants could be significantly associated with the children's respiratory health.

The type of residential building, outdoor climate, lifestyles, and cultural behaviors has substantial differences between China and the other countries (Huang et al., 2015; Zhang et al., 2013b). Indoor air quality and its impacts on childhood respiratory health in China could be different with in the other countries (Brunekreef and Holgate, 2002; Dales et al., 2008; Gordon et al., 2014). However, few studies investigated indoor air quality and its associations with childhood health in large sample size in China (Wang et al., 2008; Wu et al., 2008). To our best knowledge, none study was conducted to investigate associations of household air quality with the odds of childhood asthma by case-control design and on-site inspection in Mainland China. From 2013 to 2014, as phase two of the CCHH study in Shanghai, we conducted a case-control study and on-site inspected indoor air quality in 454 residences in Shanghai, China. In the present paper, we aimed to: 1) detailedly introduce the inspected methods; 2) preliminarily analyze the on-site measured data for indoor air quality of the residences in different inspected seasons; 3) compare our results of indoor air quality to the similar studies from other cities and countries. For the on-site measured data, we investigated correlations between indoor and outdoor concentration of particulate matters (PM_{1.0}, PM_{2.5}, PM_{4.0}, and PM₁₀), as well as correlations among six analyzed indicators/pollutants (temperature, relative humidity, carbon dioxide (CO₂), formaldehyde, airborne fungi, and particulate matters). We compared differences of these indicators/pollutants between cases and controls. We also investigated associations of these indicators/pollutants with the odds of childhood asthma. We hypothesized that the status of these analyzed indicators/pollutants has notable differences among different seasons and has robust correlations between each other, as well as has significant differences between cases and controls and has significant associations with increased odds of childhood asthma.

2. Methods

2.1. Study design and participants

The CCHH study in Shanghai included two phases: a questionnaire-based cross-sectional study (phase one) and on-site home inspection-based case-control study (phase two). From April 2011 to April 2012, we conducted the cross-sectional study in 88 randomly selected kindergartens from Shanghai's six districts (four urban districts: Yang-Pu, Hong-Kou, Zha-Bei, and Jing-An; two suburban districts: Bao-Shan and Feng-Xian) and collected 16,948 valid questionnaires from parents of 1–8 year-old children. Methods for participant selection and questionnaire survey in the cross-sectional study have been detailedly introduced in our previous articles (Huang et al., 2015; Hu et al., 2014; Liu et al., 2015a). Herein children from the pilot survey of phase one in the Yang-Pu district, were not included in the analyses of associations between home environment and childhood health by data in this phase, but were included in the selection of the inspected residences in the case-control study. In the cross-sectional study, we obtained information for dwelling environment and family lifestyle behaviors via parents by a modified questionnaire which was derived from the previous and similar studies in several countries (Bornehag et al., 2004; Naydenov et al., 2008; Sun and Sundell, 2013) and in other cities of China (Zhang et al., 2013a; Wang et al., 2013a,b). Parents also reported information for the child's history of asthma, allergy, and airway diseases by an improved questionnaire that was derived from the International Study of Asthma and Allergies in Childhood (ISAAC) (Asher et al., 1995). These information would be used to select cases and controls. A previous article has provided the whole questions in the questionnaire as [Supplemental materials](#) (Zhang et al., 2013a). Herein question for the childhood history of asthma was that "has your child been diagnosed with asthma by a doctor (yes vs. no)". We also asked parents that whether they would agree to have on-site home inspection in the case-control study (phase two) in the questionnaires. From March 2013 to December 2014, we conducted the case-control study via contacting parents who were willing to cooperate with our inspection and on-site inspecting household air quality.

The questionnaire and detailed proposals for the CCHH study in Shanghai were approved by the ethical committee in the School of Public Health, Fudan University in Shanghai, China. We informed the participants of the purpose of the study by written explanation. Before on-site inspection, both inspector and participant signed an informed consent form (one same copy for each). All participants voluntarily responded to the questionnaire and on-site inspection. The ethical committee approved this procedure for obtaining consent. We carried out the questionnaire and on-site inspection in strict accordance with the approved guidelines.

2.2. Selection of cases and controls

In the case-control study, those people who have developed the disease we were interested in were defined as cases, and a representative sample of people from the same population who do not have that disease were defined as controls; and then their home-related environmental exposures we were interested in were asked or on-site inspected (Webb and Bain, 2011). In the present study, we selected children who had history of doctor-diagnosed asthma in childhood as cases and children who did not have doctor-diagnosed asthma as controls. A total of 10,182 parents agreed to cooperate with the following home inspection and provided phone numbers in the cross-sectional study (phase one). Herein 1216 children (11.9% of the total 10,182 participants) who had history of doctor-diagnosed asthma were considered as potential cases group. All the rest 8651 children who did not have

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