



Exposure to house dust phthalates in relation to asthma and allergies in both children and adults



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HIGHLIGHTS

- We investigated house dust phthalate in Japanese dwellings.
- We examined the associations between phthalate and allergies.
- More strongly associated with children's rhinitis and atopy compared to adults.
- Significant association were only found in floor dust.
- Children are more vulnerable to phthalate exposure via floor dust than adults.

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ABSTRACT

Although an association between exposure to phthalates in house dust and childhood asthma or allergies has been reported in recent years, there have been no reports of these associations focusing on both adults and children. We aimed to investigate the relationships between phthalate levels in Japanese dwellings and the prevalence of asthma and allergies in both children and adult inhabitants in a cross-sectional study. The levels of seven phthalates in floor dust and multi-surface dust in 156 single-family homes were measured. According to a self-reported questionnaire, the prevalence of bronchial asthma, allergic rhinitis, allergic conjunctivitis, and atopic dermatitis in the 2 years preceding the study was 4.7%, 18.6%, 7.6%, and 10.3%, respectively. After evaluating the interaction effects of age and exposure categories with generalized liner mixed models, interaction effects were obtained for DiNP and bronchial asthma in adults ($P_{\text{interaction}} = 0.028$) and for DMP and allergic rhinitis in children ($P_{\text{interaction}} = 0.015$). Although not statistically significant, children had higher ORs of allergic rhinitis for DiNP, allergic conjunctivitis for DEHP, and atopic dermatitis for DiBP and BBzP than adults, and liner associations were observed ($P_{\text{trend}} < 0.05$). On the other hand, adults had a higher OR for atopic dermatitis and DEHP compared to children. No significant associations were found in phthalates levels collected from multi-surfaces. This study suggests that the levels of DMP, DEHP, DiBP, and BBzP in floor dust were associated with the prevalence of allergic rhinitis, conjunctivitis, and atopic dermatitis in children, and children are more vulnerable to phthalate exposure via household floor dust than are adults. The results from this study were shown by cross-

Abbreviations: BBzP, benzyl butyl phthalate; DBP, dibutyl phthalate; DEHA, di-2-ethylhexyl adipate; DEHP, di-2-ethylhexyl phthalate; DEP, diethyl phthalate; DiBP, di-iso-butyl phthalate; DiNP, di-iso-nonyl phthalate; DMP, dimethyl phthalate; DnBP, di-n-butyl phthalate; ETS, environmental tobacco smoke; GC/MS, gas chromatography/mass spectrometry; LOD, limit of detection; MBzP, mono benzyl phthalate; MDL, method detection limits; PVC, polyvinyl chloride; SVOC, semi-volatile organic compounds.

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sectional nature of the analyses and elaborate assessments for metabolism of phthalates were not considered. Further studies are needed to advance our understanding of phthalate toxicity.

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1. Introduction

Through the 1980s, the prevalence of asthma and allergies among children increased in developed countries (Asher et al., 2006). In fact, the increase in the prevalence of asthma and allergies in adults as well as in children has gained attention during recent years (WHO, 2005). Various reviews have focused on the associations between increasing asthma and allergies and indoor environmental factors such as house dust mite allergens, environmental tobacco smoke, mould, pets, and nitrogen dioxide. Thus, the indoor environment may have contributed to the increase in asthma and allergies. One of the reasons for increasing asthma and allergies is phthalates. Phthalates have been used as plasticisers for various plastic products, such as toys, food containers, furniture, personal care products, medical devices, and paints. And humans are exposed to phthalates throughout their lifetime, beginning in foetal stages. Due to their hand-to-mouth behaviour and eating without hand washing after playing, assessing the exposure of children to dust contaminated with SVOCs is regarded as an important issue (Wormuth et al., 2006; U.S.EPA, 2002).

Dust ingestion contributes to most to the ingestion of high-molecular-weight phthalates such as DEHP and BBzP in children (Beko et al., 2013). Because phthalates are not chemically bound to products, they can easily diffuse within materials, leach out, and then disperse into the air or adhere to airborne particles and settled dust (Fujii et al., 2003). Therefore, phthalates easily penetrate into house dust that settles on phthalate-containing products (Seto and Saito, 2002). We previously reported that high levels of DEHP in dust were detected in dwellings with polyvinyl chloride (PVC) flooring (Ait Bamai et al., 2013). The same findings were reported in previous epidemiological studies (Bornehag et al., 2005; Kolarik et al., 2008a). However, compared to other previous studies, the levels of DEHP in house dust in Japan were higher than in studies from Sweden (Bornehag et al., 2005), Bulgaria (Kolarik et al., 2008a,b), Germany (Abb et al., 2009; Fromme et al., 2004), Denmark (Langer et al., 2010) (Clausen et al., 2003), Taiwan (Hsu et al., 2012), China (Guo and Kannan, 2011), and the USA (Guo and Kannan, 2011; Rudel et al., 2003), and thus, DEHP exposure is of particular concern for Japan (Ait Bamai et al., 2013).

Since the 2000s, various experimental studies have reported that several phthalates have adjuvant effects on Th2 differentiation and Th2-promoted antigen-specific production of IgG1 and IgE in mice (Hansen et al., 2007; Larsen and Nielsen, 2007). Epidemiological studies have reported positive relationships between phthalates in dust or phthalate-related products, such as PVC flooring and asthma or allergic symptoms, since the late 1990s (Jaakkola et al., 2004, 2000, 1999; Larsson et al., 2010; Oie et al., 1997; Bornehag et al., 2004; Kolarik et al., 2008b; Callesen et al., in press-a,b). Recently, the relationship between urinary phthalate metabolites and allergic symptoms has been investigated in epidemiological studies (Bertelsen et al., 2013; Callesen et al., in press-a,b; Hoppin et al., 2013; Hsu et al., 2012; Just et al., 2012; Wang et al., 2014).

However, only four epidemiological studies regarding the relationship between phthalates in house dust and inhabitants' asthma or allergies have been reported (Kolarik et al., 2008a,b; Callesen et al., in press-a,b; Hsu et al., 2012; Bornehag et al., 2004). Previous studies evaluated only children aged 2–9 years old and did not consider allergic symptoms in teenagers and adults. To our knowledge, there have been no studies that have focused on the differences of allergic impacts on the exposure to house dust phthalates between children and adults. Therefore, the specific aim of the current study was to investigate the relationship between phthalate levels in Japanese dwellings and the

2-year prevalence of bronchial asthma and allergies among the inhabitants of such dwellings, both children and adults.

2. Materials and methods

Details of the study design and methods used for the environmental measurements have been reported previously (Araki et al., 2010; Kanazawa et al., 2010; Kishi et al., 2009; Takigawa et al., 2010); therefore, only a brief description is provided here.

2.1. Study population

This study is a second follow-up cross-sectional study that was conducted from September to December 2006; 156 detached dwellings and their 516 inhabitants were evaluated. The details of the methods have been described elsewhere (Araki et al., 2010, 2014; Kishi et al., 2009; Takigawa et al., 2010). Briefly, in 2003, questionnaires on baseline indoor-air quality were sent to 6080 randomly selected single-family homes from six regions of Japan, Sapporo, Fukushima, Nagoya, Osaka, Okayama, and Fukuoka, that had been constructed within the previous 7 years. Ultimately, 2297 households responded (a response rate of 41.1%) (Kishi et al., 2009). Of the responding households, 425 agreed to home visits for environmental measurements in 2004 (Saijo et al., 2011; Takigawa et al., 2010), and the first follow-up of 270 households was conducted in 2005. From September to December 2006, the second follow-up of 624 inhabitants in 182 single-family homes was conducted. Out of the 182 houses, 26 houses were excluded because the amount of both floor and multi-surface dust were less than 25 mg and we could not measure phthalate levels. Therefore, 516 inhabitants in 156 single-family homes where more than 25 mg of house dust from either floor or multi-surfaces and other environmental measurements could be obtained, were included in this study. Although the original study protocol was prospective, and the inhabitants agreed to allow environmental measurements over a period of 3 years, we only included the results from the second follow-up study because measurements of phthalates in house dust were only conducted in 2006. The resulting potential selection bias was addressed by comparing the participants who continued with the study to those who did not, using the data from 2003 and 2004. No significant differences were found (Araki et al., 2010).

2.2. Questionnaire

The investigators who visited each dwelling, distributed and collected questionnaires for the inhabitants to complete. All inhabitants were asked to complete the personal questionnaire which consisted of two sections: personal characteristics and symptoms of bronchial asthma and allergies. Parents completed the personal questionnaires for inhabitants younger than 6 years old. Personal characteristics included questions on gender, age, ETS (environmental tobacco smoke) (current smoker/non-smoker, ETS/non-smoker, non-ETS), time spent in the home (continuous), and self-reported stress level (high/medium/low). History of bronchial asthma, allergic rhinitis, allergic conjunctivitis, and atopic dermatitis was assessed by asking "Have you ever been seen at a hospital because of bronchial asthma in the past 2-years?"; "Have you ever been seen at a hospital because of allergic rhinitis in the past 2-years?"; "Have you ever been seen at a hospital because of allergic conjunctivitis in the past 2-years?"; "Have you ever been seen at a hospital because of atopic dermatitis in the past 2-years?" A reply of "Yes" was considered to be positive in this study (Araki et al., 2012, 2014).

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