



Associations of household dampness with asthma, allergies, and airway diseases among preschoolers in two cross-sectional studies in Chongqing, China: Repeated surveys in 2010 and 2019

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ABSTRACT

Many studies have investigated the associations between household damp indicators, and allergies and respiratory diseases in childhood. However, the findings are rather inconsistent. In 2010, we conducted a cross-sectional study of preschoolers aged three-six years in three urban districts of Chongqing, China. In 2019, we repeated this cross-sectional study with preschoolers of the same ages and districts. Here, we selected data for 2935 and 2717 preschoolers who did not change residences since birth in the 2010 and 2019 studies, respectively. We investigated associations of household damp indicators with asthma, allergic rhinitis, pneumonia, eczema, wheeze, and rhinitis in childhood in the two studies. The proportions of residences with household damp indicators and the prevalence of the studied diseases (except for allergic rhinitis) were significantly lower in 2019 than in 2010. In the two-level (district-child) logistic regression analyses, household damp exposures that showed by different indicators were significantly associated with the increased odds of lifetime-ever asthma (range of adjusted odds ratio (AOR): 1.69–3.50 in 2019; 1.13–1.90 in 2010), allergic rhinitis (1.14–2.39; 0.67–1.61), pneumonia (1.09–1.64; 1.21–1.59), eczema (0.96–1.83; 0.99–1.56), wheeze (1.64–2.79; 1.18–1.91), rhinitis (1.43–2.71; 1.08–1.58), and current (in the past 12 months before the survey) eczema (0.46–2.08; 0.99–1.48), wheeze (0.97–2.86; 1.26–2.07) and rhinitis (1.34–2.25; 1.09–1.56) in most cases. The increased odds ratios (ORs) of most diseases had exposure–response relationships with the cumulative number (*n*) of household damp indicators in the current and early residences. Our results indicated household damp exposure could be a risk factor for childhood allergic and respiratory diseases, although the magnitudes of these effects could be different in different studies.

1. Introduction

In China, the prevalence of asthma and allergic rhinitis in childhood has sharply increased in recent years (Huang et al., 2015; Sears 2014; Zhang and Zhang 2019). Since genetic heredity only affects specific groups, this increased prevalence may be associated with environmental exposures (Huang et al., 2019; Papi et al., 2018). It is important to identify the risk factors in order to provide practical guidance to minimize this increased prevalence.

Numerous studies suggest that asthma and allergic rhinitis in childhood is significantly associated with household damp exposures (Cai et al., 2019; Fan et al., 2017; Hu et al., 2014; Jaakkola et al., 2010; Jacobs et al., 2014; Lin et al., 2015; Mendell and Kumagai, 2017;

Norback et al., 2017; Pind et al., 2017; Quansah et al., 2012; Reboux et al., 2019; Sahakian et al., 2008; Shorter et al., 2018; Sun et al., 2017; Wang et al., 2015; Weinmayr et al., 2013; Yang et al., 2018). However, findings in these studies were not consistent (Jaakkola et al., 2013; Kennedy and Grimes, 2013). Specifically, in eight European birth-cohort studies, damp exposures in the first two years of life significantly increased (39%) the odds of parental-reported early asthma symptoms, and increased (12%) the odds of allergic rhinitis symptoms among school children (Tischer et al., 2011). A birth-cohort study of 396 children found that the severity of damp damage in kitchens and visible mold in the main living area (especially in the child's bedroom) was significantly associated with wheezing (Karvonen et al., 2009). However, this study found that damp damage in bathrooms and in other

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interior spaces was not associated with wheezing symptoms, and found that cough and respiratory infections were not associated with moisture and mold exposure in different spaces around the home (Karvonen et al., 2009).

Although many of the above studies found significant associations of household damp exposures with allergies and respiratory diseases in childhood (Cai et al., 2019; Fan et al., 2017; Hu et al., 2014; Jaakkola et al., 2010; Jacobs et al., 2014; Lin et al., 2015; Mendell and Kumagai, 2017; Norback et al., 2017; Pind et al., 2017; Reboux et al., 2019; Shorter et al., 2018; Sun et al., 2017; Wang et al., 2015; Weinmayr et al., 2013; Yang et al., 2018), it is hard to inspect long-term dampness-related exposures in households and estimate their causal effects on childhood allergies and airway diseases in a large sample size (Jaakkola et al., 2013). Few studies investigated causal relationships between household damp exposures and childhood allergies and respiratory diseases. These causal relationships could be partly examined using a longitudinal repeated study, which is in line with the time sequence and thus has a strong ability to verify the etiology between a suspicious factor and health outcomes (Mendell et al., 2011; Jaakkola et al., 2013). In the past decades, building materials and technologies have substantially improved in China (National Bureau of Statistics of China, 2018), and thus we speculate that household-dampness-related problems could be notably decreased. These fast-changing situations provide a good opportunity to investigate the effects of different levels of household-dampness-related exposures on health problems among children by longitudinally repeated surveys in the same regions.

In this paper, based on a cross-sectional study in 2010 and a repeated cross-sectional study in 2019 in Chongqing, China, we investigated associations of household damp indicators with childhood asthma, allergies, and airway diseases. Our study could be the first repeated survey on comparing associations of damp exposures in residences with childhood respiratory diseases among preschoolers in the same city in China. Our study partly suggests the causal effects of household damp exposures on childhood allergies and respiratory health, although this causal relationship could not be confirmed due to the study design. We hypothesize that household damp indicators are significantly associated and number-responded with the studied diseases in the two studies.

2. Methods

2.1. Study subjects

Chongqing city is located in southwest China and has hot summers and cold winters with high outdoor relative humidity throughout the year (Wang et al., 2015). Since household development of damp indicators has strong associations with the relative humidity of indoor air (Fan et al., 2017), the unique climatic conditions in Chongqing city provide an excellent chance to investigate associations of household damp exposures with childhood allergies and respiratory health. Besides, in the past 10 years, the economic level of Chongqing has rapidly increased. Living environments and household damp problems in Chongqing have improved compared to those of 10 years ago. This situation also provides a good chance to verify associations of household dampness with childhood allergies and respiratory health among populations with different levels of exposure to household damp.

From December 2010 to March 2011, a cross-sectional study of household environments and childhood asthma and allergies was conducted in Chongqing city (Wang et al., 2015) as a part of the CCHH (China, Children, Homes, Health) study which was conducted in 10 Chinese cities (Zhang et al., 2013). In this study, we distributed questionnaires to the preschool children's parents or guardians through the children's teachers in the surveyed kindergartens (Fig. 1). We used a multistage cluster sampling method to select these kindergartens. First, we coded all urban districts of Chongqing city and chose three districts by lottery. Then, in each selected district, all kindergartens were coded

and about 18 kindergartens were randomly selected by lottery. With the assumption that asthma prevalence among Chongqing preschoolers in 2010 was 8.0% and the marginal error of this estimate did not exceed 2% with a 95% confidence level, the sample size was at least 707 preschoolers according to the equation to estimate sample size in the binary outcome-descriptive study (Hajian-Tilaki, 2011). Finally, 54 kindergartens were randomly selected from three districts (Jiulongpo District, Shapingba District, and Yubei District) of Chongqing city. We surveyed 7,117 children 1–8 years old and received 5,299 valid questionnaires (response rate: 74.5%). We excluded questionnaires with missing information on the child's age and questionnaires for children whose sample sizes were small. A total of 2,935 three to six years-old children who had not changed residence since birth were selected as the basic sample for the data analysis. We called this study “the 2010 study”.

During June 2019, we conducted a repeated cross-sectional study in 34 kindergartens from the same districts of Chongqing city (Fig. 1), and used the same questionnaire as in the 2010 study. In this repeated study, we first contacted the same kindergartens as in the 2010 study. If a kindergarten did not agree to enroll in the survey, the nearest kindergarten to it was contacted. About two-thirds (23/34) of the surveyed kindergartens were the same as in the 2010 study. In this study, we also distributed questionnaires to the preschool children's parents through the children's teachers. We surveyed 6,547 children 1–8 years old and received 4,943 valid questionnaires (response rate: 75.5%). Here we also excluded questionnaires with missing information on the child's age and questionnaires for children whose sample sizes were small. A total of 2,717 three to six years-old children who had not changed their residence since birth were selected as the basic samples for the data analysis. We called this study “the 2019 study”.

The study and the consent procedure were approved by the Ethics Committee of the School of Public Health, Fudan University. Fudan University was a cooperating institution in the CCHH study and was responsible for obtaining the ethical approval for this study. The consent from all parents or guardians of the children involved was obtained before the survey.

2.2. Household damp exposures

Questionnaires for household damp indicators were derived from the Dampness in Buildings and Health (DBH) study in Sweden (Bornehag et al., 2005). Six damp indicators: visible mold spots, visible damp stains, water damage, damp clothing/bedding, condensation on windowpanes, and moldy odors were surveyed for the current residences. Three damp indicators: visible mold/damp spots, condensation on windowpanes, and moldy odors, were surveyed for the child's residence at birth (the early residence). The specific questions for these damp indicators are presented in Table S1. A “yes” answer defines that the child was exposed to the corresponding damp indicators. The cumulative number (*n*) of damp indicators in early and current residences shows the exposure–response relationships for household damp exposures and health outcomes. Besides, if no damp indicators were reported in the early and current residences, this defines that that particular child had “never” been exposed to damp. If any damp indicators were reported in the early residence, but none in the current residence, that child was defined as having “only early” damp exposure. Similar definitions were used for the “only current” and “both” damp exposure categories.

2.3. Health outcomes

We obtained information for health outcomes using questions from the International Study of Asthma and Allergies in Childhood (ISAAC) (Asher et al., 1995). In this study, we analyzed nine health outcomes: asthma, allergic rhinitis, pneumonia, eczema, wheeze, and rhinitis at any stage of life (lifetime-ever), as well as eczema, wheeze, and rhinitis

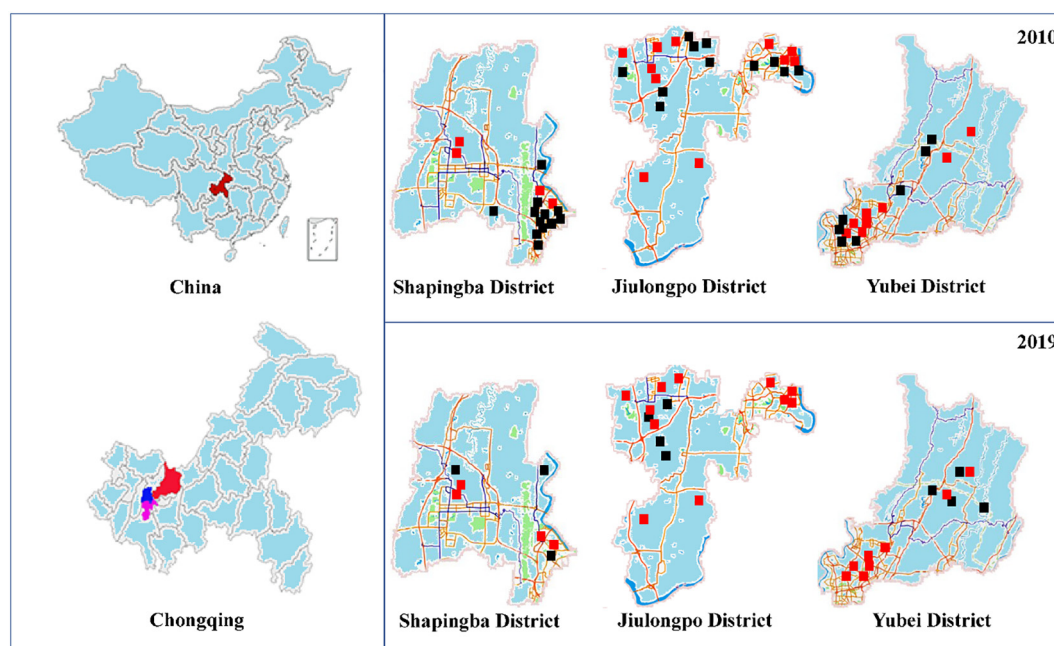


Fig. 1. Location for the surveyed kindergartens in the two studies. The block schemes indicate locations of the surveyed kindergartens. The block schemes in red indicate the kindergartens that were surveyed in both studies.

in the last 12 months before the survey (current). Questions for these health outcomes are presented in Table S2. A “yes” answer defines that the child had the corresponding diseases. Herein, asthma, allergic rhinitis, and pneumonia were common airway diseases and doctor-diagnosed whereas eczema, wheeze, and rhinitis were self-reported symptoms. Since wheeze and rhinitis are typical symptoms for asthma and allergic rhinitis respectively, they were both chosen as health outcomes in this study which compares the associations of household-dampness-related exposures with diseases and symptoms.

2.4. Statistical analysis

All statistical analyses were performed using SPSS 20.0 (IBM Ltd., USA) and STATA 11.0 (STATA Corp., Texas, USA). Children with complete data for all required variables were selected in the analysis. Pearson's chi-square test was applied to compare the different proportions of household damp exposures between the 2010 and the 2019 studies. We also applied Pearson's chi-square test to compare the different prevalences of health outcomes between the two studies, as well as in the different subgroups that stratify the household damp exposures. A p -value < 0.05 was considered to be statistically significant.

When considering the multistage sampling method, we used two-level (district-child) logistic regression models to investigate associations and exposure–response relationships between household damp exposures and health outcomes. According to findings from previous studies (Cai et al., 2019; Hu et al., 2014; Wang et al., 2015), we considered the child's age, sex, family atopic history, residential ownership, duration of breastfeeding, household renovation during early lifetime, and household environmental tobacco smoke as covariates in the logistic regression models. Adjusted odd ratios (AORs) with a 95% confidence interval (CIs) were used to show the target associations and exposure–response relationships.

3. Results

Among the 2,935 children in the 2010 study (Table 1), about 33% were four-years old. A total of 50.3% of children were boys, and 11.3% of children had a family atopic history. About 63.8% of children were

Table 1
Demographic information in the two studies.

Items	Sample size, n (%)		p -value
	2010 ($N = 2935$)	2019 ($N = 2717$)	
Age (years old)			
3	669 (22.8)	303 (11.2)	
4	959 (32.7)	768 (28.3)	
5	867 (29.5)	874 (32.2)	
6	440 (15.0)	772 (28.4)	< 0.001
Sex			
Male	1467 (50.3)	1352 (50.3)	
Female	1450 (49.7)	1335 (49.7)	0.985
Family atopic history			
Yes	322 (11.3)	753 (30.1)	
No	2532 (88.7)	1746 (69.9)	< 0.001
Residential ownership			
Owner	1818 (63.8)	2067 (81.5)	
Renter	1032 (36.2)	469 (18.5)	< 0.001
Breastfeeding duration			
≤ 6 months	1414 (49.3)	1330 (49.5)	
> 6 months	1452 (50.7)	1357 (50.5)	0.905
Household renovation during early lifetime			
Yes	385 (18.6)	206 (9.3)	
No	1688 (81.4)	2015 (90.7)	< 0.001
Household environmental tobacco smoke			
Yes	1866 (64.9)	1295 (50.5)	
No	1008 (35.1)	1270 (49.5)	< 0.001

Bold indicates statistical significance.

from families who owned their residence; 49.3% of children were breastfed ≤ 6 months. A total of 18.6% children experienced household renovation during their early lifetime; and 64.9% of children were exposed to household environmental tobacco smoke. Among the 2,717 children in the 2019 study (Table 1), about 33% were five-years old. A total of 50.3% of children were boys, and 30.1% of children had a family atopic history. About 81.5% of children were from families who owned their residence; 49.5% of children were breastfed ≤ 6 months. A total of 9.3% of children experienced household renovation during their early lifetime; and 50.5% of children were exposed to household environmental tobacco smoke. Except for the child's sex and breastfeeding

Table 2
Status of household damp indicators in the two studies.

Indicators	Proportion, n (%)		p-value
	2010	2019	
In the current residence			
Visible mold spots	151 (5.6)	71 (3.2)	< 0.001
Visible damp stains	220 (8.1)	44 (2.0)	< 0.001
Damp clothing/bedding	991 (34.5)	263 (11.8)	< 0.001
Water damage	252 (9.6)	134 (6.1)	< 0.001
Condensation on windowpanes	816 (32.1)	88 (4.0)	< 0.001
Moldy odor	294 (11.6)	167 (7.6)	< 0.001
In the early residence at the child's birth			
Visible mold/damp spots	421 (14.8)	151 (6.9)	< 0.001
Condensation on windowpanes	1082 (38.3)	89 (4.1)	< 0.001
Moldy odor	309 (12.0)	150 (6.8)	< 0.001
The cumulative number of damp indicators in the current residence			
n = 0	849 (44.0)	1709 (78.9)	
n = 1	630 (32.6)	292 (13.5)	
n ≥ 2	451 (23.4)	164 (7.6)	< 0.001
The cumulative number of damp indicators in the early residence			
n = 0	1337 (53.5)	1893 (87.3)	
n = 1	842 (33.6)	195 (9.0)	
n ≥ 2	322 (12.9)	81 (3.7)	< 0.001
The cumulative location with damp indicators in the current and early residence			
Never	648 (35.0)	1617 (75.0)	
Only current	379 (20.4)	264 (12.2)	
Only early	172 (9.3)	89 (4.1)	
Both	655 (35.3)	187 (8.7)	< 0.001

Bold indicates statistical significance.

duration, the proportions of children with the various different demographic factors were significantly different between the 2010 and the 2019 studies (Table 1).

With respect to household damp indicators (Table 2), the proportions of children who were reported with household damp exposures for different indicators in the current residence and in the early residence at the child's birth were significantly higher in the 2010 study than in the 2019 study. Taking condensation on windowpanes as an example, 32.1% of current residences and 38.3% of early residences reported this indicator in the 2010 study, whereas only 4.0% of current residences and 4.1% of early residences reported it in the 2019 study.

For the studied diseases (Table 3), except for allergic rhinitis, lifetime-ever prevalences (from birth to the time of survey) and in the past 12 months were significantly higher in the 2010 study than in 2019. For example, 51.5% of children were reported with lifetime-ever rhinitis in the 2010 study, while only 30.0% were so reported in the 2019 study.

In both the 2010 and the 2019 study (Table S3-S11), children with household damp exposures that identified using various indicators had higher prevalences of diseases than children without these exposures, and the differences in the prevalences of most diseases were significant.

Table 3
Status of the studied diseases in the two studies.

Diseases	Prevalence, n (%)		p-value
	2010	2019	
Lifetime-ever (From birth to the time of survey)			
Asthma	255 (8.8)	157 (6.4)	0.001
Allergic rhinitis	185 (6.4)	238 (9.2)	< 0.001
Pneumonia	918 (31.9)	704 (26.5)	< 0.001
Eczema	885 (30.8)	532 (20.5)	< 0.001
Wheeze	749 (26.0)	282 (10.7)	< 0.001
Rhinitis	1486 (51.5)	791 (30.0)	< 0.001
Current (in the past 12 months)			
Eczema	388 (13.5)	110 (4.2)	< 0.001
Wheeze	568 (19.8)	214 (8.2)	< 0.001
Rhinitis	1125 (38.9)	616 (23.4)	< 0.001

Bold indicates statistical significance.

Herein, prevalence differences for lifetime-ever wheeze and current wheeze and rhinitis were statistically significant in all pairs. With respect to exposure-response relationships (Table S12), the cumulative numbers of household damp indicators in the current residences or in the early residences generally had significant exposure-response relationships with the prevalences of the studied diseases. For a combination of household damp indicators in the current and early residences, children who only had household damp indicators in the early residences generally had higher prevalences of the studied diseases than children who only had household damp indicators in the current residences, especially in the 2019 study.

In the association analyses, associations of household damp exposures in the current and early residences with the increased odds of most diseases were significant (Fig. 2, Fig. 3, and Table S13). The ranges of adjusted odds ratio (AOR) were 1.69–3.50 in 2019 and 1.13–1.90 in 2010 for lifetime-ever asthma, as well as 1.14–2.39 and 0.67–1.61 for lifetime-ever allergic rhinitis, 1.09–1.64 and 1.21–1.59 for lifetime-ever pneumonia, 0.96–1.83 and 0.99–1.56 for lifetime-ever eczema, 1.64–2.79 and 1.18–1.91 for lifetime-ever wheeze, 1.43–2.71 and 1.08–1.58 for lifetime-ever rhinitis, 0.46–2.08 and 0.99–1.48 for current (in the past 12 months before the survey) eczema, 0.97–2.86 and 1.26–2.07 for current wheeze, and 1.34–2.25 and 1.09–1.56 for current rhinitis in 2019 and in 2010, respectively.

In the analyses of the exposure-response relationships (Fig. 4, Fig. 5, and Table S14), most diseases positively number-responded with the cumulative numbers (n) of household damp indicators in the current and early residences. These exposure-response relationships for lifetime-ever asthma, allergic rhinitis, and wheeze were stronger among children with damp exposures in the current residence than in the early residence (Fig. 4). However, the exposure-response relationships for pneumonia, eczema, and rhinitis were stronger among children with damp exposures in the early residence than in the current residence (Fig. 4). Except for lifetime-ever asthma and current eczema and wheeze, only early residence household damp indicators had stronger associations than only current residence household damp indicators with the studied diseases in both the 2010 and 2019 studies (Fig. 5). Specifically, in the 2019 study, compared to children in the lowest grades (n = 0 or none exposure), children in the highest grades (n ≥ 2 or had damp exposures in both current and early residences) had about 200% and 150% higher odds of being reported with asthma and wheeze, respectively.

4. Discussion

In this study, we found that proportions of residences with damp indicators and the prevalence of asthma, pneumonia, eczema, wheeze, and rhinitis were significantly higher in the 2010 study than in the repeated 2019 study. Children with household damp exposures had higher prevalences than children without these exposures. Household damp exposures were significantly associated with the increased odds of most diseases in both studies. The increased odds ratios (ORs) of most diseases had exposure-response relationships with the cumulative number (n) of household damp indicators in the two studies.

Our findings for associations of damp exposures with childhood allergic and respiratory diseases were consistent with previous studies (Bornehag et al., 2005; Cai et al., 2019; Choi et al., 2014; Hu et al., 2014; Wang et al., 2015; Tischer et al., 2011; Mendell et al., 2018). The ranges of AORs for associations between household damp exposures with asthma and wheeze in childhood were similar to the AOR ranges (1.40 to 2.20) in a review of the related studies from before 2004 (Bornehag et al., 2004). The DBH study in Sweden, using the same questionnaire as the present study, also found that household damp exposures, indicated as floor moisture, water leakage, visible mold/damp spots, and condensation on windowpanes, had significant associations with asthma, wheeze, and rhinitis among the 1–6 years old preschoolers (Bornehag et al., 2005). In a series of reviews, Mendell

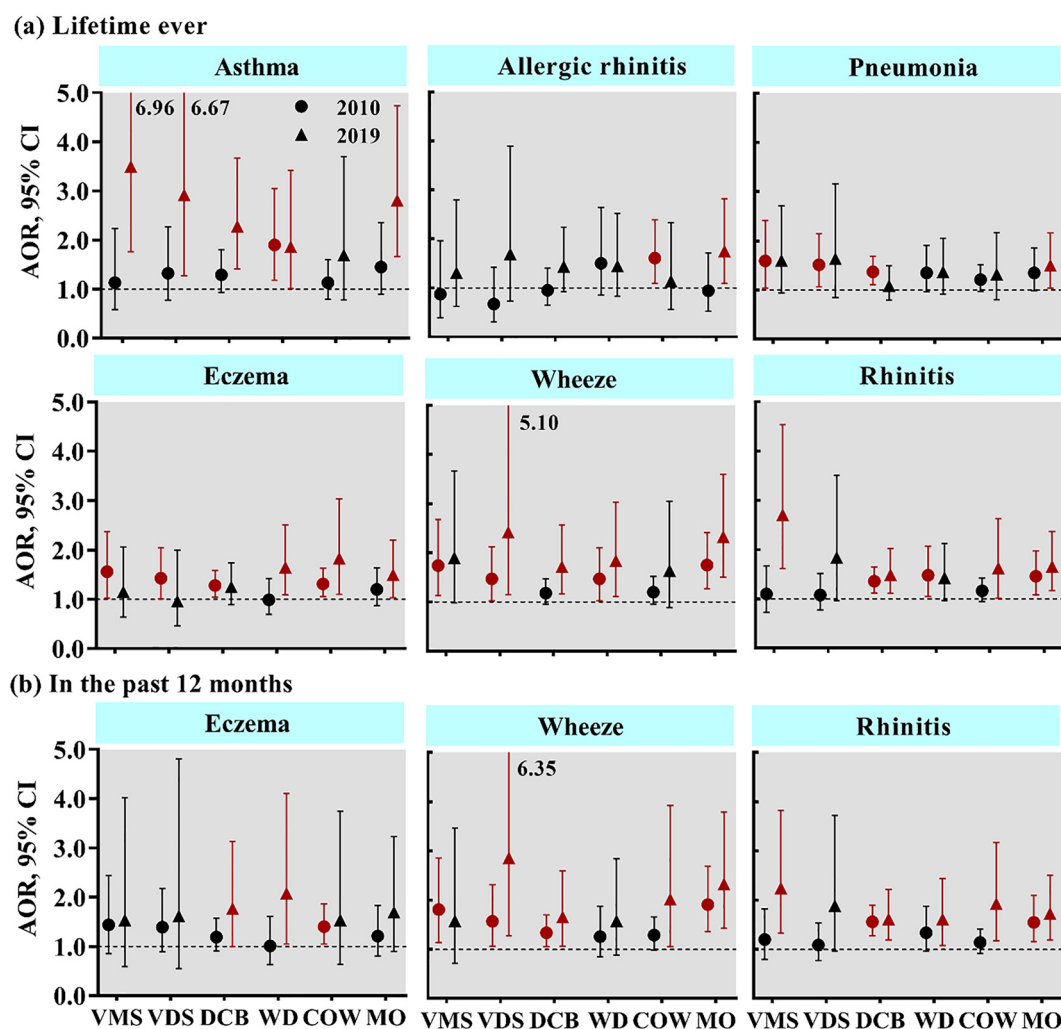


Fig. 2. Comparisons on associations of asthma, allergies, and airway diseases among preschoolers with household damp indicators in the current residence in the two studies. Adjusted factors include the child's age, sex, family atopic history, residential ownership, breastfeeding duration, household renovation during early lifetime, and household environmental tobacco smoke. VMS, visible mold spots; VDS, visible damp stains; DCB, damp clothing/bedding; WD, water damage; COW, condensation on windowpane; MO, moldy odor, AOR, adjusted odds ratio, CI, confidence interval. The dots in red indicate that the corresponding AORs are statistically significant (p -value < 0.05). The detailed values for AORs and their 95% CIs are presented in the supplemental Table S13.

et al. found that damp exposures in households were significantly associated with the development of allergic symptoms among children from different cities or regions and with different demographic characteristics (Mendell *et al.*, 2011, 2018). These findings consistently confirmed that household damp exposures are risk factors for asthma and rhinitis in childhood.

Our findings for the exposure-response relationships of damp indicators with the increased odds of presenting with the studied diseases were consistent with several previous studies (Cai *et al.*, 2019; Norbäck *et al.*, 2013; Hu *et al.* 2014; Shorter *et al.*, 2018; Weinmayr *et al.*, 2013). In New Zealand, a case-control study found that indoor visible mold and mold odor were positively dose-dependent with the increased odds of wheeze (ranges of AORs: 1.30 to 3.56) (Shorter *et al.*, 2018). In 12 European countries, The ECRHS (European Community Respiratory Health Survey) found that indoor mold and water damage was dose-responsive with the new onset of asthma in young adults (Norbäck *et al.*, 2013). These consistent exposure-response relationships further suggest that household damp exposures seemingly had causal relationships with allergies and respiratory diseases in childhood. The metrics from observation-based studies of the effect of household damp exposures on respiratory health in childhood could also be developed according to these exposure-response relationships (Mendell and Kumagai, 2017).

Our finding that associations of household dampness-related exposures with asthma, allergic rhinitis, and their related symptoms were stronger among children with these exposures only in their early residences rather than only in their current residences, was consistent with several previous studies (Cai *et al.*, 2019; Hu *et al.*, 2014; Bornehag *et al.*, 2005; Quansah *et al.*, 2012). In the CCHH study of 4–6 years-old preschoolers in Shanghai, China, Hu *et al.* also found that children with household dampness-related exposures only in their early residence had higher odds of getting allergies and airway diseases than children with these exposures only in the current residence (Hu *et al.*, 2014). These findings suggest that the effects of household-dampness-related exposures during early lifetime on childhood asthma, allergic rhinitis, and their related symptoms could be stronger than that occurring currently.

Our findings that proportions of residences with damp indicators and prevalences of the studied diseases (except for allergic rhinitis) were significantly higher in the 2010 study than in the 2019 study, seemingly suggest that problems with household damp exposures as well as allergic and respiratory diseases among preschoolers in Chongqing improved over the past 10 years. Since many studies reported that household damp exposures were associated with childhood allergies and respiratory diseases, parents in Chongqing could be aware of the need to reduce indoor damp exposures. However, these

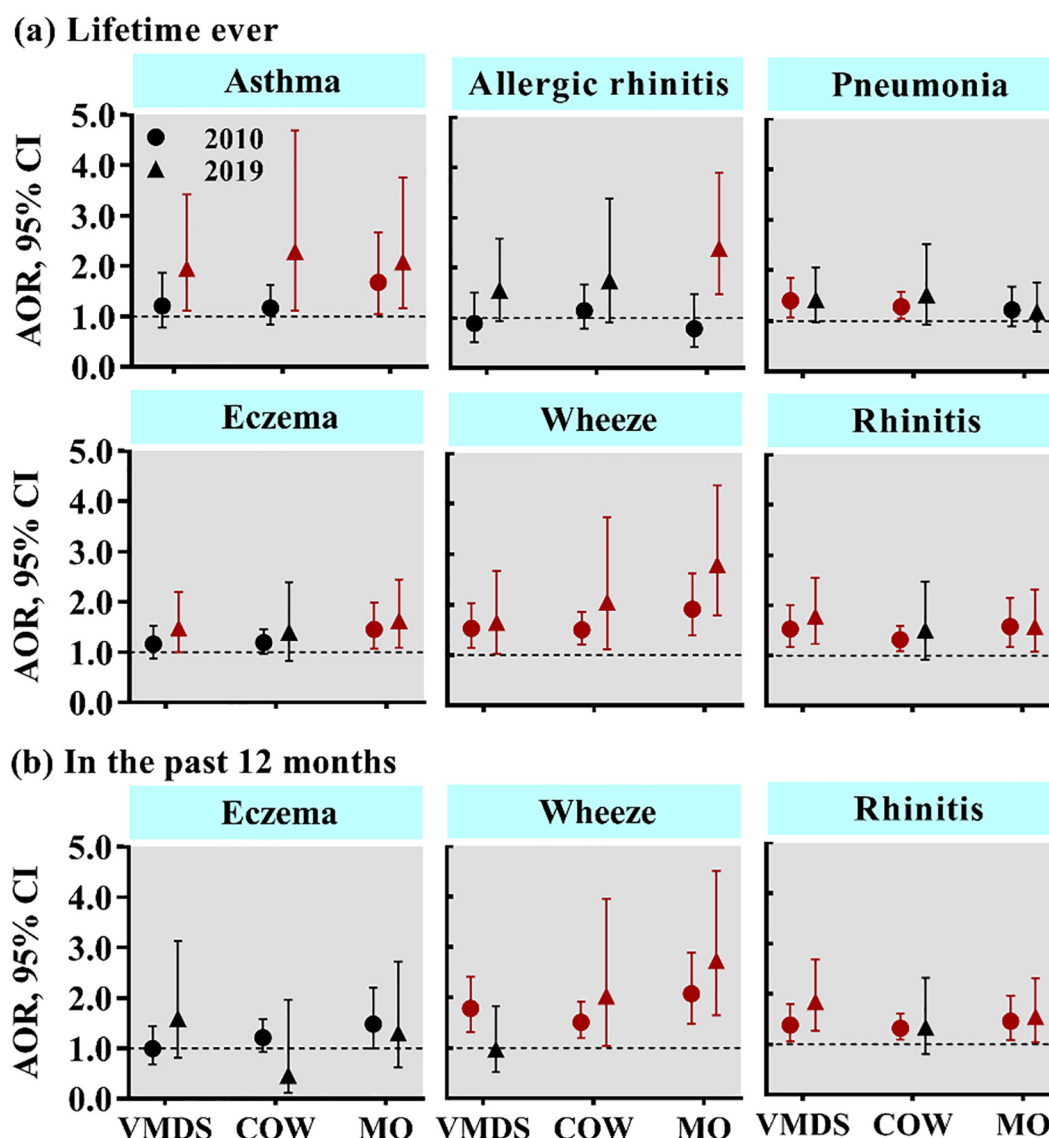


Fig. 3. Comparisons of the associations of asthma, allergies, and airway diseases among preschoolers with household damp indicators in their early residences in the two studies. Adjusted factors include the child's age, sex, family atopic history, residential ownership, breastfeeding duration, household renovation during early lifetime, and household environmental tobacco smoke. VMDS, visible mold/damp spots; COW, condensation on windowpane; MO, moldy odor, AOR, adjusted odds ratio, CI, confidence interval. The dots in red indicate that the corresponding AORs are statistically significant (p -value < 0.05). The detailed values for AORs and their 95% CIs are presented in the supplemental Table S13.

differences in the proportions of damp problems and in prevalences may also be related to the different survey periods (Liu et al., 2015, 2020b). Questionnaires in the 2010 cross-sectional study were conducted during winter-spring when it was cold-humid in Chongqing, whereas the 2019 cross-sectional study was conducted during summer when it was warm. Our additional analyses showed that proportions of children with damp clothing/bedding and condensation on windowpanes were significantly lower among March-surveyed children than December- and January-surveyed children (Table S15). These findings seemingly suggest that our questionnaire could have a limited capacity in catching the information for damp clothing/bedding and condensation on windowpanes during a certain period before the survey. It also suggests that the survey period could have an effect on the reported information for household damp problems and that this should be considered in similar studies and analyses. Nevertheless, in both studies, exposures to household damp problems were in most cases consistently associated with increased odds of allergies and respiratory diseases in childhood. These findings further confirm that household damp exposures are risk factors for childhood allergies and respiratory

diseases and should receive more attention in order to control and improve childhood health.

This study has some limitations. First, no direct inference for causality of household damp exposures with respiratory health outcomes in childhood can be made in this questionnaire-based study, although our exposure-response relationships and the repeated study seemingly suggest this causality. Second, there are perhaps other factors that were not considered in this study which could confound the studied associations. They mainly include dietary habits (Andrusaityte et al., 2017), maternal nutrition (Beckhaus et al., 2015), and outdoor air pollution (Liu et al., 2016, 2020a). Third, our associations could be confounded by the potential for over-reporting damp exposures that parents were aware of before the survey (Larsson et al., 2011) and of children's symptoms. Fourth, as we discussed above, the survey periods in the 2010 study and in the 2019 study were different, this could have an impact on the comparability of the reported information for household damp problems.

However, in Chongqing, parents' knowledge of the health effects of damp indicators in households could have been limited in 2010. No

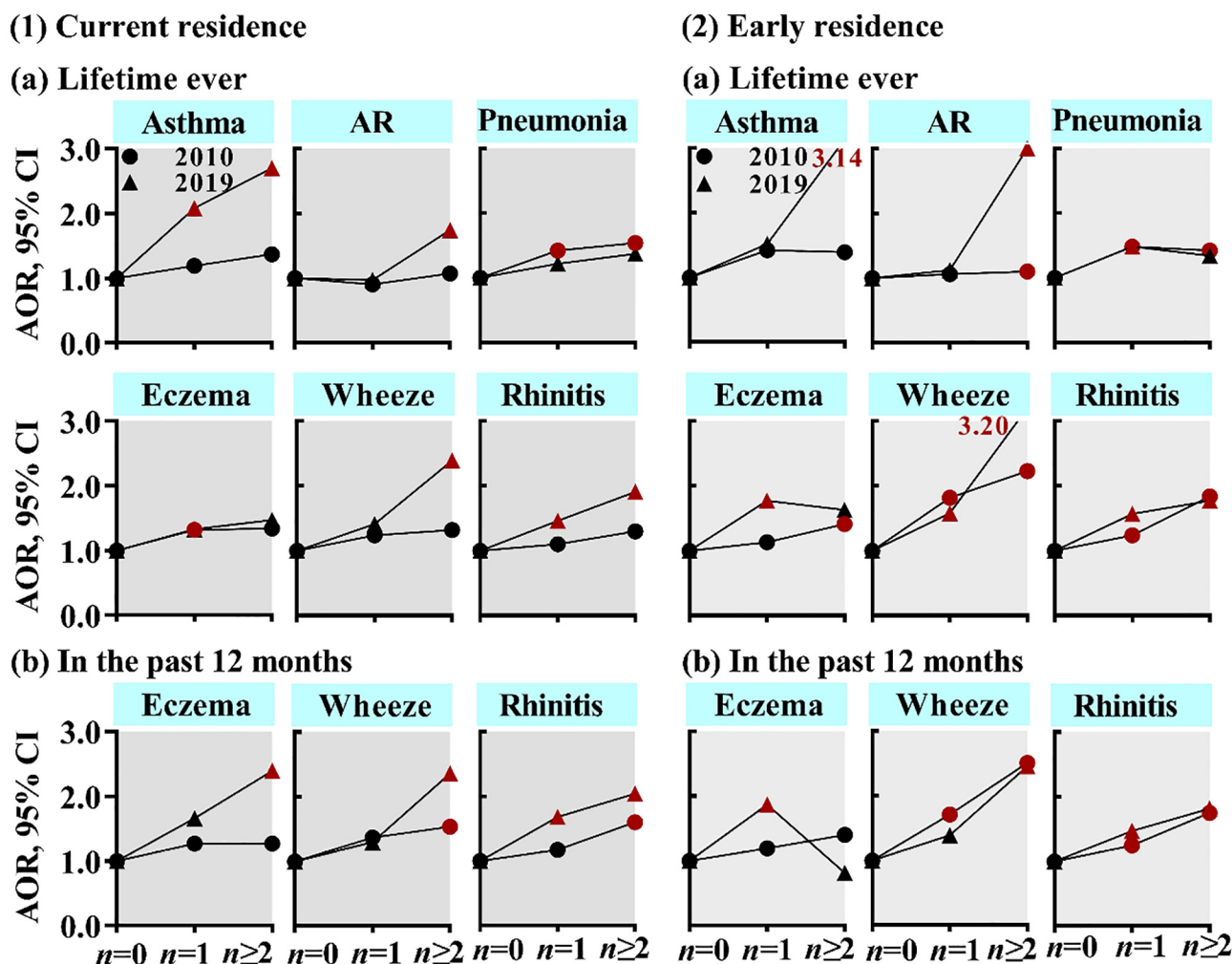


Fig. 4. Exposure-response relationships of the cumulative numbers (n) for household damp indicators in the current and early residence with odds for asthma, allergies, and airway diseases in the two studies. Adjusted factors included the child's age, sex, family atopic history, residential ownership, breastfeeding duration, household renovation during early lifetime, and household environmental tobacco smoke. AR, allergic rhinitis; AOR, adjusted odds ratio; CI, confidence interval. The dots in red indicate that the corresponding AORs are statistically significant (p -value < 0.05). The detailed values for AORs and their 95% CIs are presented in the supplemental Table S14.

large information campaign about the risk factors for asthma and allergies has happened in China. Our findings probably were not confounded by the reported bias in the 2010 study. In the repeated 2019 study of preschoolers of the same age, although problems of household damp exposures were notably better than in the 2010 study, this seemingly had a partial relationship with the awareness to reduce indoor damp exposures. However, exposures to household damp problems in 2019 were consistently associated with the increased odds of allergies and respiratory diseases in childhood.

5. Conclusions

Household damp exposures in the early and current residences are associated with the increased odds of lifetime-ever asthma, allergic rhinitis, pneumonia, eczema, wheeze, and rhinitis as well as current eczema, wheeze, and rhinitis among preschoolers in Chongqing, China, in 2010 and in 2019. Impacts of household-dampness-related exposures on childhood asthma, allergic rhinitis, and their related symptoms could be stronger during early lifetime than currently. Although the problems of household-dampness-related exposures are likely to have been improved in 2019 compared with 2010, and effect magnitudes could be different in different studies, our results further confirm that early and current household damp exposures are risk factors for allergic

and respiratory diseases among preschoolers.

CRediT authorship contribution statement

Jiao Cai: Conceptualization, Methodology, Software, Investigation, Visualization, Data curation, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition. **Baizhan Li:** Conceptualization, Methodology, Software, Investigation, Visualization, Data curation, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition. **Wei Yu:** Conceptualization, Methodology, Software, Investigation, Visualization, Data curation, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition. **Yinghui Yao:** Investigation, Visualization, Data curation, Writing - original draft. **Lexiang Wang:** Investigation, Visualization, Data curation, Writing - original draft. **Bicheng Li:** Investigation, Visualization, Data curation, Writing - original draft. **Yujue Wang:** Investigation, Visualization, Data curation, Writing - original draft. **Chenqiu Du:** Investigation, Visualization, Data curation, Writing - original draft, Supervision, Funding acquisition. **Jie Xiong:** Investigation, Visualization, Data curation, Writing - original draft.

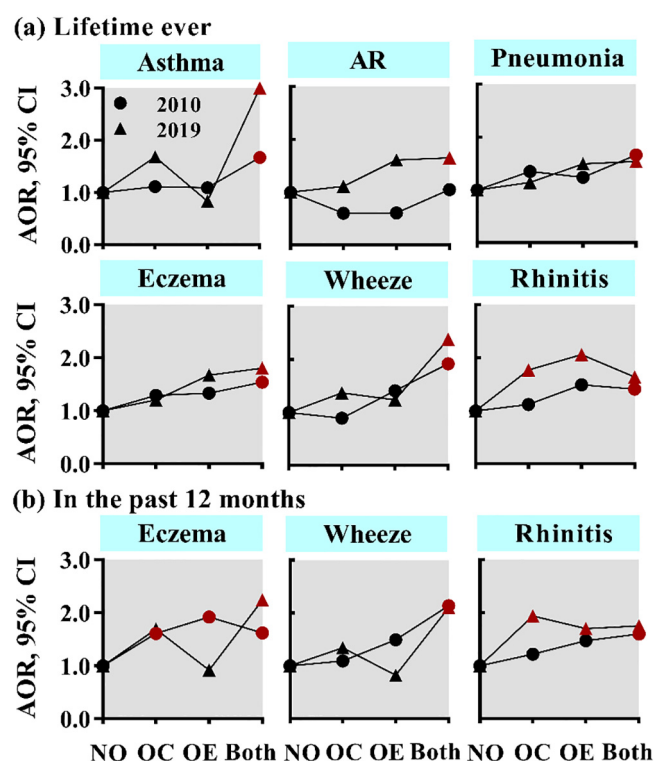


Fig. 5. Exposure-response relationships of combinations of household damp indicators in the early and current residences with odds for asthma, allergies, and airway diseases in the two studies. Adjusted factors included the child's age, sex, family atopic history, residential ownership, breastfeeding duration, household renovation during early lifetime, and household environmental tobacco smoke. AR, allergic rhinitis; NO, none; OC, only in the current residence; OE, only in the early residence; Both, both in the current and early residence; AOR, adjusted odds ratio, CI, confidence interval. The dots in red indicate that the corresponding AORs are statistically significant (p -value < 0.05). The detailed values for AORs and their 95% CIs are presented in the supplemental Table S14.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.envint.2020.105752>.

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