



Asthma, allergic rhinitis and eczema among parents of preschool children in relation to climate, and dampness and mold in dwellings in China

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ABSTRACT

The main aim was to study associations between asthma, allergic rhinitis and eczema among adults across China and dampness and mold at home. Young adults ($N = 40,279$) in eight cities in China answered a questionnaire in 2010–2012 (response rate 75.0%). Data on asthma, allergic rhinitis, eczema and the home environment was assessed by the questionnaire. Climate data was obtained from China Meteorological Administration and the website of Weather Underground. Health associations were analyzed by two-level logistic regression models, adjusting for covariates. Totally 1.6% had asthma, 6.6% allergic rhinitis and 2.2% eczema. Mold odor was associated with asthma ($OR = 1.90$) and allergic rhinitis ($OR = 1.25$ – 1.44). Window pane condensation in winter was associated with asthma ($OR = 1.39$), allergic rhinitis ($OR = 1.26$ – 1.58) and eczema ($OR = 1.36$ – 1.77). Presence of mold spots or damp stains was related to asthma ($OR = 1.58$ – 2.49), allergic rhinitis ($OR = 1.35$ – 1.76) and eczema ($OR = 1.47$ – 1.70). Water damage was related to asthma ($OR = 1.69$ – 1.82), allergic rhinitis ($OR = 1.40$ – 1.45) and eczema ($OR = 1.44$ – 1.96). Damp bed clothing was related to asthma ($OR = 1.23$), allergic rhinitis ($OR = 1.23$) and eczema ($OR = 1.35$). A higher dampness score was associated with increased odds ratios for diseases. Those living in older buildings had more asthma ($OR = 1.39$ – 1.76) and allergic rhinitis ($OR = 1.16$ – 1.21). Those living in suburban or rural areas had less asthma, allergic rhinitis and eczema as compared to those living in urban areas (OR values from 0.24 to 0.66). Stronger health associations with dampness and mold were found in southern China and in newer buildings (constructed after 2005). In conclusion, dampness and mold at home can be risk factors for asthma, allergic rhinitis and eczema among adults in China. Living in older buildings can be risk factors for asthma or allergic rhinitis while living in less urbanized areas can be protective.

1. Introduction

Asthma is a common chronic inflammatory airway disease. Rhinitis is characterized by irritation and inflammation of the nasal mucosa.

Asthma and rhinitis can be categorized as allergic or non-allergic (Settipane and Charnock, 2007). Atopic dermatitis (or atopic eczema) is a chronic skin disease more common among infants or children than adults (Eichenfield et al., 2014). Asthma and allergic rhinitis are the

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most commonly reported comorbidities for atopic dermatitis (Chiesa Fuxench, 2017).

Asthma prevalence varies from 1 to 18% in different part of the world (GINA Report, 2017), with the highest prevalence (6.0%–12.0%) in developed western countries (Lundback et al., 2016). Asthma seems to be still increasing globally, with the most pronounced increase in low and middle-income countries (Lundback et al., 2016; Baiz and Annesi-Maesano, 2012; Asher et al., 2006; Lai et al., 2009). About 10%–20% of the population in USA and Europe are affected by allergic rhinitis (Ozdoganoglu and Songu, 2012). Some studies reported that adult allergic rhinitis have increased in the past decades (Bjerg et al., 2011; Zhang and Zhang, 2014; de Marco et al., 2012). According to the International Study of Asthma and Allergies in Childhood (ISAAC) study, > 20% of the children are affected by eczema in some countries (Odhiambo et al., 2009). Atopic dermatitis is less common in the adult population. It has been estimated that 1–3% of the adult population is affected by atopic dermatitis (Eichenfield et al., 2014; Deckert et al., 2014).

Environmental risk factors in dwellings can include allergens, dampness and mold (WHO, 2009), insufficient ventilation (Sundell et al., 2011), and chemical emissions from building materials (Mendell, 2007). Signs of dampness, such as water leakage, water damage, visible mold and mold odor, are often linked to biological contaminants such as house dust mites (Zock et al., 2002; Weinmayr et al., 2013), mold (Sahlberg et al., 2013) and bacteria (Sahlberg et al., 2013). Furthermore, indoor dampness and mold can lead to emission of microbial volatile organic compounds (Sahlberg et al., 2013) and chemicals due to degradation of building materials (Norback et al., 2000).

Reviews have concluded that dampness and mold in dwellings are consistent risk factors for current asthma and asthma symptoms including wheeze and cough (WHO, 2009; Fisk et al., 2007). Moreover, dampness and mold in dwellings is associated with increased prevalence of doctor diagnosed asthma (Fisk et al., 2007) and increased asthma incidence (Quansah et al., 2012; Heinrich, 2011). However, most of the studies included in these reviews are on children. Some prevalence studies from Nordic countries are available for adults. In Sweden, dampness in the floor construction in dwellings was associated with current asthma among adults (Norback et al., 1999). In Finland, signs of moisture or dampness at home were associated with nocturnal dyspnea (Koskinen et al., 1999), wheeze (Koskinen et al., 1999) and physician diagnosed asthma (Kilpelainen et al., 2001) among adults. In Norway, mold or water damage at home was associated with doctor diagnosed asthma and wheeze among adults (Skorge et al., 2005). Moreover, one longitudinal multicentre study reported that water damage and mold in dwellings were associated with adult onset of asthma (Norback et al., 2013).

According to a review and meta-analysis, indoor dampness and mold can increase the risk of rhinitis (Jaakkola et al., 2013). Most of the studies included in this review were on children. There are a few studies available on dampness or mold and adult rhinitis. Dampness at home was associated with hay fever among Swedish adults (Engvall et al., 2001). Signs of dampness or mold in dwellings were related to rhinitis (Koskinen et al., 1999; Pirhonen et al., 1996) and physician diagnosed allergic rhinitis (Kilpelainen et al., 2001) among adults in Finland. One recent Chinese study found that dampness in dwellings was associated with rhinitis symptoms among adults (Zhang et al., 2019).

Some publications on eczema/dermatitis among school children are available. The ISAAC phase two study (20 countries were included) found that residential dampness and mold was associated with increased eczema among school children (8–12 y) (Weinmayr et al., 2013). Visible mold at home in Japan was associated with atopic dermatitis among elementary school children (Ukawa et al., 2013). Dampness at home was associated with doctor diagnosed atopic eczema among school children in Belarus (Shpakou et al., 2012) and UK (McNally et al., 2001). We found only one dampness study among adults. This study reported associations between home dampness and

physician diagnosed atopic eczema among university students in Finland (Kilpelainen et al., 2001).

Among different dampness indicators, mold odor has been reported to have the strongest association with asthma onset (Quansah et al., 2012) and rhinitis (Jaakkola et al., 2013). Some studies have reported health associations for mold odor among adults. Mold odor at home was associated with asthma symptoms (Engvall et al., 2001) and hay fever (Engvall et al., 2001; Norback et al., 2014) among adults in Sweden. Mildew odor or musty odor in dwellings was associated with asthma symptoms and rhinitis symptoms among adults in USA (Shiue, 2015). Another study from USA (including mainly adults) found that mildew/musty odor in homes was associated with doctor diagnosed asthma and doctor diagnosed eczema (Sharpe et al., 2015). One recent study from China reported that, among all dampness indicators, mold odor had the strongest associations for current rhinitis symptoms (Zhang et al., 2019). We found no studies on mold odor and eczema/dermatitis.

Window pane condensation in winter is another dampness indicator which is related to insufficient ventilation and high air humidity. There are few studies on associations between window pane condensation and adult asthma or rhinitis. One Swedish study found that window pane condensation at home was a risk factor for onset of asthma symptoms among civil aviation pilots (Fu et al., 2016). Studies from Japan found that window pane condensation in homes was related to wheeze (Takaoka and Norback, 2011) and rhinitis (Saijo et al., 2009) among adults. Two studies from China reported that window pane condensation was associated with allergic rhinitis (Wang et al., 2014) and current rhinitis symptoms (Zhang et al., 2019). We found no studies on window pane condensation and eczema/dermatitis.

Dampness and indoor mold is common in China. One Chinese study including seven Northeast cities found that about 10% reported mold/mildew at home in the past 12 months (Dong et al., 2013). Another Chinese study from Taiyuan showed that 20% of homes had dampness/mold problems in the past 12 months (Fan et al., 2017). Few Chinese studies have investigated associations between dampness at home and asthma, rhinitis or eczema in adults. Self-reported mold/mildew at home was related to allergic rhinitis among Chinese women (Dong et al., 2013). Moreover, dampness at home was associated with asthma and rhinitis among Chinese adults (Wang et al., 2014; Lu et al., 2016). There is a need for more epidemiological studies on risk factors in the home environment for adult asthma, rhinitis or eczema in China. The CCHH (China, Children, Homes, Health) is a large multicentre study including participants across China (Zhang et al., 2013). The main aim of this study is to evaluate associations between asthma, allergic rhinitis and eczema among adults across China and indoor dampness and mold at home. The following hypotheses were tested: indicators of dampness and mold in homes are associated with asthma, allergic rhinitis and eczema among adults in China.

2. Methods

2.1. Study design and target population

The current study is a questionnaire survey from the CCHH (China, Children, Homes, Health) project. This project has been described in detail in previous studies (Zhang et al., 2019; Zhang et al., 2013; Norback et al., 2018). All children (1–8 y) from selected day care centres in eight major cities in China were invited to answer a questionnaire during November 2010 to April 2012. The questionnaire was distributed to children's parents or guardians (one parent or guardian per child) through teachers in day care centres in eight cities and was returned within one week. The full CCHH questionnaire can be found elsewhere (Zhang et al., 2013). The eight study centres, included three northern cities (Urumqi, Beijing and Taiyuan) and five southern cities (Nanjing, Shanghai, Wuhan, Chongqing and Changsha), are all megacities with populations ranged from three to 34 million. The populations in Beijing, Shanghai and Chongqing are over 19 million.

Totally 59,817 questionnaires were distributed and 44,859 were completed (response rate 75.0%). Among the completed questionnaires, 40,279 were answered by children's parents (one parent per child), 2441 were answered by children's grandparents (one grandparent per child), 450 were answered by other persons (not specified), and 1889 questionnaires had no information on the respondents. The current study is restricted to questionnaires answered by children's parents (one parent per child) since our aim is to study parents' asthma, rhinitis and eczema in relation to home environment. Thus, a total of 40,279 questionnaires were included (67.8% from southern China).

2.2. Ethics statement

The study and the consent procedure were approved by the Medical Research Ethics Committee of School of Public Health, Fudan University. All participants gave informed consent.

2.3. Assessment of health

There were two questions (each with three sub-questions) asking for parents' asthma/allergies:

(1) Father: asthma (yes/no); allergies in the nose or eyes (yes/no); eczema (yes/no).

(2) Mother: asthma (yes/no); allergies in the nose or eyes (yes/no); eczema (yes/no).

Moreover, there was one question asking who answered the questionnaire (father/mother).

Based on the questions above, three health variables were created: asthma (yes/no); allergies in the nose or eyes (yes/no); eczema (yes/no) for the parents answering the questionnaire (participants).

2.4. Assessment of precipitation and ambient temperature on city level

Annual precipitation for each city were obtained from China Meteorological Administration. Mean annual precipitation from 1971 to 2000 were obtained for Urumqi, Beijing and Taiyuan. For Nanjing, Shanghai, Wuhan and Chongqing, the mean annual precipitation were calculated based on data from 1981 to 2010. The mean annual precipitation for Changsha were calculated based on data from 1971 to 2013. The average ambient temperature for each city was obtained in 2010, 2011 and 2012 from the website of Weather Underground (<https://www.wunderground.com>). Mean ambient temperature from 2010 to 2012 were calculated for all centres.

2.5. Assessment of demographic and socioeconomic data

Information on gender, current smoking habit, second hand smoke (SHS), maternal occupation during pregnancy and home size ($\leq 60 \text{ m}^2$ / $61\text{--}100 \text{ m}^2$ / $> 100 \text{ m}^2$) were collected from the questionnaire. SHS was defined as passive smoking exposure from the spouse. The question on maternal occupation during pregnancy had ten alternatives: unemployed, housewife, farmer, industrial worker, office staff, teacher, medical staff, student, shop assistant and other occupations. Maternal occupation was categorized to four groups: not occupationally active (unemployed, housewife), farmer, industrial worker and white-collar worker (office staff, teacher, medical staff, student, shop assistant and other occupations). Maternal occupation during pregnancy was used to classify both men and women's socio-economic status. Home size was demonstrated to be a good social-economic indicator related to household income (Juhn et al., 2011), and has been used in two previous Chinese studies as an indicator of socio-economic status (SES) (Zhang et al., 2019; Norback et al., 2018).

2.6. Assessment of exposure at home

Questions on home exposure included:

(1) House site (urban/suburban/rural);

(2) Building construction year (before 1980/1980–1990/1991–2000/2001–2005/after 2005);

(3) Ownership of the home (yes/no);

(4) Mold odor at home after child's birth (yes, often/yes, sometimes/no); “yes, often” and “yes, sometimes” were combined as “yes” for further analysis.

(5) Mold odor in the current home in the past three months (yes, often/yes, sometimes/no); “yes, often” and “yes, sometimes” were combined as “yes” for further analysis.

(6) Window pane condensation during winter at home after child's birth (yes/no);

(7) Window pane condensation during winter in the current home (yes/no);

(8) Mold spots or damp stains at home after child's birth (yes/no);

(9) Mold spots in the current home (yes/no);

(10) Damp stains in the current home (yes/no);

(11) Water damage in the current home (yes, in the past years/yes, in the past 12 months/no); only one alternative could be chosen for this question;

(12) Damp bed clothing in the current home in the past 12 months (yes, often/yes, sometimes/no); “yes, often” and “yes, sometimes” were combined as “yes” for the data analysis.

Based on the questions mentioned above, two new combined dampness variables were created: “mold odor” and “mold spots or damp stains”. All these two new dampness variables had four alternatives: never, only in the past years (period from child's birth to now), only currently and both.

Moreover, one combined variable “window pane condensation in winter” was created based on question (6) and (7) above. The variable had four alternatives: never, only in the past years (period from child's birth to now), only currently and both.

As a next step, a continuous dampness score (0–6) was created based on the numbers of dampness indicators as follows: mold odor after child's birth (“no” coded as 0, “yes” coded as 1); mold odor in the current home in the past three months (0,1); mold spots or damp stains after child's birth (0,1); mold spots or damp stains in the current home (0,1); water damage in the current home (0,1) and damp bed clothing in the current home (0,1). The continuous dampness score (0–8) were used to create a categorized dampness score (0–4). The categorized dampness score (0–3) was defined as such: score 0, without any dampness indicator; score 1, one dampness indicator; score 2, two dampness indicators; score 3, more than two dampness indicators.

2.7. Statistical analysis

Chi-square test was applied to compare self-reported asthma, allergic rhinitis, eczema regarding demographic and socioeconomic data, house site and construction year. Moreover, Chi-square test was applied to compare the prevalence of different dampness indicators and window pane condensation in winter regarding different house sites. Factor analysis was applied for dampness indicators, window pane condensation, home size, house site, construction year and ownership of the dwelling, using principal component analysis and varimax rotation. Kendall's tau-b correlation was applied to analyze correlations between four signs of indoor dampness and mold and window pane condensation, and between precipitation and ambient temperature. Initially, associations between health variables and all covariates (gender, current smoking, SHS, home size and maternal occupation during pregnancy) were analyzed, by mutual adjusting including all

covariates in two-level (city level and individual level) logistic regression models. As a next step, two-level logistic regression models (city level and individual level) were applied to estimate the associations between health variables and indoor dampness and mold and window pane condensation, adjusting for covariates (one exposure variable for each model). Interaction analyses were applied to estimate the differences in associations between dampness indicators, window pane condensation and asthma, allergic rhinitis and eczema in northern and southern cities, in new and old buildings (constructed after 2005 vs. other) and in self-owned and rented dwellings. Similar two-level logistic regression models were applied to estimate the associations between categorized dampness score (0–3) and asthma, allergic rhinitis and eczema. Finally, similar two-level logistic regression models were applied to estimate associations between climate, northern/southern cities, house site, construction year, ownership and asthma, allergic rhinitis and eczema, by adding dampness score in the models. The statistical analysis was performed using SPSS 25.0 (SPSS Inc., Chicago, IL, USA) and STATA 15.1 (multi-level logistic regression). The

associations were expressed as odds ratios (OR) with a 95% confidence interval (CI) for logistic regressions. In all statistical analyses, a two-tailed test and a 5% level of significance were applied.

3. Results

Totally 40,279 participants were included in this study with 74.7% women. The mean age of the women were 32.8 ± 4.1 years (range 21–53 y). While there was no information available for the ages of the male participants, the men are expected to have a similar age range as the women. About one third of the participants were from northern cities (10.6% from Urumqi, 13.1% from Beijing and 8.6% from Taiyuan). The majority (67.8%) were from southern cities (Nanjing 9.3%, Shanghai 33.5%, Wuhan 4.8%, Chongqing 11.2% and Changsha 8.9%). Self-reported asthma, allergic rhinitis and eczema were 1.6%, 6.6% and 2.2%, respectively. Participants from southern cities had more often asthma (1.7% vs. 1.3%) and eczema (2.5% vs. 1.5%) than those from northern cities (Table 2). Self-reported asthma was highest in Shanghai (1.9%), and lowest in Taiyuan (0.8%). Self-reported allergic rhinitis was highest in Urumqi (7.8%), while lowest in Chongqing (2.7%). Eczema was most common in Shanghai (3.2%), and least common in Taiyuan (0.5%) (Table 1).

Data on mean annual precipitation and mean ambient temperature are given for each centre in Table 1. Southern cities had generally higher mean annual precipitation and higher mean ambient temperature than northern cities.

The majority were females (74.7%) and 12.2% were current smokers. About half of the male participants (45.3%) were current smokers while only 1.0% of the females were smokers. One third of the participants (34.8%) were exposed to SHS. Most lived in small size dwellings with an area < 100 m². The majority of the dwellings were located in urban area (75.4%). Half of the participants (52.4%) were living in buildings constructed after year 2000, and more than half (64.0%) owned their dwellings. Self-owned dwellings were more common among buildings constructed after 2001 as compared to older buildings (constructed before 2001) (Table S1).

Table 2 compares asthma, allergic rhinitis and eczema among

Table 1

Self-reported asthma (%), allergic rhinitis (%) and eczema (%) among young parents and mean annual precipitation and mean ambient temperature on city level for eight centres.

Centre	Asthma (%)	Allergic rhinitis (%)	Eczema (%)	Mean annual precipitation (mm)	Mean ambient temperature (°C) ^a
Urumqi	1.7	7.8	1.2	286	8.2
Beijing	1.4	8.3	2.3	572	11.8
Taiyuan	0.8	3.5	0.5	431	10.4
Nanjing	1.3	5.4	1.7	1091	15.9
Shanghai	1.9	8.2	3.2	1166	17.2
Wuhan	1.7	7.1	2.1	1316	16.8
Chongqing	1.6	2.7	1.6	1108	18.3
Changsha	1.6	5.1	2.2	1331	17.7

^a The mean ambient temperature (°C) for each city was calculated based on data on annual mean outdoor temperature (°C) in 2010, 2011 and 2012 on city level.

Table 2

Self-reported asthma (%), allergic rhinitis (%) and eczema (%) among young parents from eight centres (*n* = 40,279).

	Total (%)	Asthma (%)	<i>p</i> ^a	Allergic rhinitis (%)	<i>p</i> ^a	Eczema (%)	<i>p</i> ^a
Total		1.6		6.6		2.2	
Northern/southern cities ^b							
Northern	32.2	1.3	0.002	6.8	0.154	1.5	< 0.001
Southern	67.8	1.7		6.5		2.5	
Gender							
Male	25.3	2.0	< 0.001	5.5	< 0.001	1.6	< 0.001
Female	74.7	1.5		6.9		2.4	
Current smoker							
Yes	12.2	1.8	0.159	4.3	< 0.001	1.7	0.007
No	87.8	1.5		6.0		2–3	
Second hand smoke (SHS)							
Yes	34.8	1.6	0.907	6.2	0.029	2.4	0.144
No	65.2	1.6		6.8		2.1	
Maternal occupation during pregnancy							
Not occupationally active ^a	39.3	1.5	0.390	5.0	< 0.001	1.9	< 0.001
Farmer	1.6	1.7		2.9		0.7	
Industrial worker	3.8	1.5		3.9		1.6	
White-collar worker ^b	55.3	1.7		8.0		2.5	
Home size							
≤ 60 m ²	26.9	1.7	0.839	5.1	< 0.001	1.8	0.001
61–100 m ²	41.7	1.6		6.5		2.2	
> 100 m ²	31.3	1.6		8.1		2.5	
House site							
Urban	75.4	1.8	< 0.001	7.5	< 0.001	2.4	0.001
Suburban	20.9	0.9		4.4		1.8	
Rural	3.7	1.2		2.1		1.2	
Construction year							
After 2005	20.2	1.1	0.002	6.0	< 0.001	1.8	0.013
2001–2005	32.2	1.7		7.4		2.4	
1991–2000	28.0	1.7		6.7		2.4	
Before 1991	19.6	1.8		6.3		2.3	
Ownership							
Self-owned	64.0	1.6	0.505	7.5	< 0.001	2.3	0.047
Rented	36.0	1.5		5.1		2.0	

^a By Chi-square test.

^b Northern cities included Urumqi, Beijing and Taiyuan. South cities included Nanjing, Shanghai, Wuhan, Chongqing and Changsha.

Table 3
Home environment characteristics stratified by location of the city, ownership and house site ($n = 40,279$).

Category	Subcategory	Total (%)	Northern (%)	Southern (%)	Urban (%)	Suburban (%)	Rural (%)	p^a	Self-owned (%)	Rented (%)	p^a
Mold odor	Never	85.8	89.5	84.0	86.8	83.7	77.6	< 0.001	88.0	82.0	< 0.001
	Only in past years ^b	4.1	3.3	4.5	3.8	5.2	5.5		3.8	4.7	
	Only currently	5.6	4.1	6.4	5.4	6.3	8.4		3.8	7.2	
Window pane condensation in winter	Both	4.4	3.2	5.0	4.0	4.9	8.5		3.4	6.1	
	Never	37.9	38.3	37.6	37.1	38.0	51.3	< 0.001	35.5	42.1	< 0.001
	Only in past years ^b	11.5	13.9	10.2	11.3	11.4	16.3		11.0	12.5	
Mold spots or damp stains	Only currently	9.6	11.0	8.9	10.0	8.7	7.6		9.8	9.3	
	Both	41.0	36.8	43.3	41.7	41.9	24.7		43.8	36.1	
	Never	78.1	81.0	76.8	78.8	76.8	70.4	< 0.001	79.9	74.7	< 0.001
Water damage in current residence	Only in past years ^b	8.5	7.5	8.9	8.4	8.6	10.4		8.2	9.0	
	Only currently	8.2	7.0	8.8	8.0	9.0	10.1		7.5	9.7	
	Both	5.2	4.5	5.5	4.8	5.1	9.0		4.3	6.7	
Damp bed clothing in current residence	Never	85.3	84.0	85.9	85.2	85.1	86.9	0.096	85.0	85.5	0.175
	In the past years	7.8	8.4	7.5	7.7	8.3	6.9		8.0	7.4	
	In the past 12 months	7.0	7.6	6.6	7.1	6.6	6.2		7.0	7.0	
Damp bed clothing in current residence	Yes	32.8	19.0	39.3	30.8	37.8	44.4	< 0.001	29.6	38.5	< 0.001

^a Chi-square test.

^b 1–8 years ago (after the child was born).

different groups. Males had more often asthma (2.0% vs. 1.5%), and females had more often allergic rhinitis (6.9% vs. 5.5%) and eczema (2.4% vs. 1.6%). Smokers had less allergic rhinitis and less eczema and those exposed to SHS from their spouse had less allergic rhinitis. Size of the home was related to allergic rhinitis and eczema. If the mother were white-collar workers during pregnancy, allergic rhinitis (8.0%) and eczema (2.5%) were more common among the participants. Moreover, those living in urban areas had more asthma (1.8%), allergic rhinitis (7.5%) and eczema (2.4%). Participants living in the newest buildings had least asthma and eczema. Allergic rhinitis (7.4%) was most common among participants living in buildings constructed during 2001–2005. Participants living in self-owned dwellings had more allergic rhinitis and eczema.

Home environment data are shown in Table 3. Window pane condensation in winter (62.1%) and damp bed clothing (32.8%) were common indoor problems. Totally 14.1% reported mold odor (in the past years or in the current home), 21.9% mold spots or damp stains (in the past years or in the current home), and 14.8% water damage in the current home. Southern cities had more mold odor, window pane condensation in winter, mold spots or damp stains and damp bed clothing. Water damage was more common in northern cities. Dwellings from rural areas had more mold odor, mold spots or damp stains and damp bed clothing but less window pane condensation in winter. Rented dwellings had more often mold odor, mold spots or damp stains and damp bed clothing, but less window pane condensation in winter (as compared to self-owned dwellings).

Factor analysis of the home environment factors identified two factors. The first factor included mold odor, mold spots or damp stains and damp bed clothing. The second factor included construction year, home size and ownership. Self-owned dwellings were associated with larger home size and newer buildings. House site (urban/suburban/rural), window pane condensation in winter and water damage were not included in any factor.

Correlation analysis for four dampness indicators and window pane condensation in winter showed that mold odor was weakly associated with mold spots or damp stains (Kendall's tau-b = 0.277) and damp bed clothing (Kendall's tau-b = 0.253). Mold spots or damp stains was weakly associated with water damage (Kendall's tau-b = 0.250) and damp bed clothing (Kendall's tau-b = 0.245). All the other correlation coefficients were lower than 0.2.

Precipitation was strongly associated with ambient temperature (Kendall's tau-b = 0.663) according to correlation analysis.

Associations between the covariates and asthma, allergic rhinitis and eczema were analyzed in mutually adjusted models (Table 4). Males had more asthma but less eczema. Current smoking and SHS were associated with less allergic rhinitis. Those living in larger home had less allergic rhinitis and eczema. Moreover, allergic rhinitis and eczema were more common if the mother were white-collar workers during pregnancy.

As a next step, two-level logistic regression models were applied to estimate associations between dampness indicators, window pane condensation and asthma, allergic rhinitis and eczema (Table 5). Mold odor was a risk factor for asthma and allergic rhinitis. Window pane condensation in winter (especially if exposed both in the past years and in the current home) was associated with asthma, allergic rhinitis and eczema. Mold spots or damp stains and water damage in the current home were related to asthma, allergic rhinitis and eczema. Furthermore, damp bed clothing was related to asthma, allergic rhinitis and eczema.

Health associations for the categorized dampness score (0–3) was analyzed in Table 6. A higher score of signs of dampness in the home was associated with increased OR values for asthma, allergic rhinitis and eczema.

Associations between climate, northern/southern cities, house site, construction year, ownership and asthma, allergic rhinitis and eczema were analyzed adjusting for dampness score (Table 7). Living in

Table 4

Associations between co-variates and self-reported asthma, allergic rhinitis and eczema among young parents by two level logistic regression models OR (95%CI)^a (*n* = 40,279).

Variable	Subcategory	Asthma	<i>p</i>	Allergic rhinitis	<i>p</i>	Eczema	<i>p</i>
Male	Male	1.57(1.24,1.97)	< 0.001	0.90(0.80,1.02)	0.113	0.68(0.54,0.86)	0.001
Current smoker	Yes	0.91(0.68,1.20)	0.495	0.71(0.60,0.85)	< 0.001	1.09(0.81,1.47)	0.567
Second hand smoke (SHS)	Yes	1.21(0.99,1.47)	0.059	0.90(0.82,0.99)	0.028	1.08(0.93,1.26)	0.325
Home size	≤60 m ²	1.00		1.00		1.00	
	61–100 m ²	0.94(0.78,1.15)	0.565	0.84(0.77,0.92)	< 0.001	0.95(0.81,1.10)	0.532
	> 100 m ²	0.96(0.77,1.19)	0.679	0.66(0.59,0.74)	< 0.001	0.73(0.61,0.89)	0.002
Maternal occupation during pregnancy	Not occupationally active ^b	1.00		1.00		1.00	
	Farmer	1.05(0.53,2.06)	0.889	0.72(0.44,1.17)	0.184	0.43(0.16,1.16)	0.096
	Industrial worker	1.01(0.64,1.59)	0.966	0.81(0.61,1.08)	0.150	1.03(0.67,1.58)	0.905
	White-collar worker ^c	1.19(0.996,1.42)	0.056	1.49(1.36,1.63)	< 0.001	1.32(1.13,1.53)	< 0.001

^a Two level logistic regression models (city, individual).

^b House wife or unemployed.

^c White-collar worker was defined as office staff, teacher, medical staff, student, shop assistant and other occupations.

Table 5

Associations between dampness indicators and self-reported asthma, allergic rhinitis and eczema among young parents by two level logistic regression models OR (95%CI)^a (*n* = 40,279).

Category	Subcategory	Asthma	<i>p</i>	Allergic rhinitis	<i>p</i>	Eczema	<i>p</i>
Mold odor	Never	1.00		1.00		1.00	
	Only in past years ^b	1.38(0.93,2.05)	0.109	1.44(1.18,1.77)	< 0.001	1.20(0.84,1.71)	0.322
	Only currently	1.22(0.86,1.74)	0.267	1.25(1.05,1.50)	0.013	1.21(0.90,1.61)	0.209
	Both	1.90(1.36,2.65)	< 0.001	1.34(1.09,1.64)	0.005	1.28(0.92,1.79)	0.146
Window pane condensation in winter	Never	1.00		1.00		1.00	
	Only in past years ^b	1.21(0.89,1.66)	0.226	1.26(1.07,1.49)	0.007	1.17(0.86,1.60)	0.311
	Only currently	1.25(0.90,1.75)	0.182	1.05(0.87,1.26)	0.628	1.36(1.00,1.84)	0.049
	Both	1.39(1.13,1.72)	0.002	1.58(1.42,1.76)	< 0.001	1.77(1.46,2.15)	< 0.001
Mold spots or damp stains	Never	1.00		1.00		1.00	
	Only in past years ^b	1.26(0.94,1.70)	0.127	1.35(1.17,1.56)	< 0.001	1.47(1.15,1.86)	0.002
	Only currently	1.58(1.20,2.08)	0.001	1.37(1.18,1.58)	< 0.001	1.70(1.36,2.12)	< 0.001
	Both	2.49(1.88,3.31)	< 0.001	1.76(1.49,2.08)	< 0.001	1.50(1.12,2.02)	0.007
Water damage in current residence	Never	1.00		1.00		1.00	
	In the past years	1.69(1.29,2.22)	< 0.001	1.40(1.21,1.62)	< 0.001	1.96(1.58,2.44)	< 0.001
	In the past 12 months	1.82(1.38,2.41)	< 0.001	1.45(1.25,1.68)	< 0.001	1.44(1.12,1.87)	0.005
Damp bed clothing in current residence	Yes	1.23(1.03,1.46)	0.020	1.23(1.12,1.34)	< 0.001	1.35(1.16,1.56)	< 0.001

^a Two level logistic regression models (city, individual). Odds ratios were adjusted for gender, current smoking, second hand smoke (SHS), home size and maternal occupation during pregnancy.

^b 1–8 years ago (after the child was born).

Table 6

Associations between categorized dampness score (0–3) and self-reported asthma, allergic rhinitis and eczema among young parents by two level logistic regression models OR (95%CI)^a (*n* = 40,279).

Score	Asthma	<i>p</i>	Allergic rhinitis	<i>p</i>	Eczema	<i>p</i>
Dampness score (0–3) ^b						
0	1.00		1.00		1.00	
1	1.40(1.11,1.77)	0.004	1.23(1.10,1.38)	< 0.001	1.41(1.17,1.71)	< 0.001
2	1.50(1.10,2.04)	0.010	1.59(1.38,1.84)	< 0.001	1.75(1.38,2.22)	< 0.001
3	1.85(1.29,2.66)	0.001	1.58(1.31,1.90)	< 0.001	2.06(1.55,2.75)	< 0.001

^a Two level logistic regression models (city, individual). Odds ratios were adjusted for gender, current smoking, second hand smoke (SHS), home size and maternal occupation during pregnancy.

^b Dampness score (0–3): score 0, without any dampness indicator; score 1, one dampness indicator; score 2, two dampness indicators; score 3, more than two dampness indicators.

suburban or rural areas was related to less asthma, allergic rhinitis or eczema. Buildings constructed before 2005 were related to asthma, buildings constructed during 2001–2005 and constructed before 1991 were related to allergic rhinitis. Moreover, self-owned dwellings were associated with allergic rhinitis.

Moreover, associations between climate, northern/southern cities, house site, construction year, ownership and asthma, allergic rhinitis and eczema were analyzed in similar two-level logistic regression models adjusting for covariates but not dampness score (Table S2). Several extra associations were found as compared to models with adjusting for dampness score in Table 7. Higher precipitation, higher

temperature, southern cities and buildings constructed before 2005 were associated with more eczema. Different results showed by Tables 7 and S2 could be explained by the covariance with dampness score.

Finally, interaction analyses were applied to identify differences in associations between dampness indicators and health variables, regarding northern/southern cities, construction year (constructed after 2005 vs. other) and ownership. Stronger associations were found between mold odor and allergic rhinitis in northern cities (interaction *p* = 0.097), between window pane condensation and allergic rhinitis in southern cities (interaction *p* = 0.061), between window pane condensation and eczema in southern cities (interaction *p* = 0.005) and

Table 7

Associations between climate, northern/southern cities, house site, construction year, ownership and asthma, allergic rhinitis and eczema by two level logistic regression models with adjustment for dampness score OR (95%CI)^a (*n* = 40,279).

Category	Subcategory	Asthma	<i>p</i>	Allergic rhinitis	<i>p</i>	Eczema	<i>p</i>
Precipitation ^b		1.19(0.75,1.85)	0.454	0.89(0.44,1.83)	0.757	2.09(0.99,4.38)	0.052
Mean temperature ^c		1.02(0.97,1.07)	0.392	0.97(0.90,1.05)	0.505	1.08(1.00,1.17)	0.057
Northern/southern cities	Northern	1.00		1.00		1.00	
	Southern	1.15(0.82,1.64)	0.417	0.88(0.50,1.57)	0.674	1.68(0.90,3.13)	0.105
House site	Urban	1.00		1.00		1.00	
	Suburban	0.45(0.33,0.63)	< 0.001	0.60(0.52,0.69)	< 0.001	0.66(0.53,0.83)	< 0.001
	Rural	0.58(0.28,1.19)	0.139	0.24(0.14,0.43)	< 0.001	0.58(0.31,1.10)	0.096
Construction year	After 2005	1.00		1.00		1.00	
	2001–2005	1.39(1.02,1.89)	0.038	1.16(1.01,1.33)	0.031	1.22(0.96,1.54)	0.100
	1991–2000	1.41(1.02,1.95)	0.038	1.10(0.95,1.28)	0.200	1.12(0.87,1.44)	0.392
	Before 1991	1.76(1.23,2.53)	0.002	1.21 (1.01,1.44)	0.033	1.22(0.91,1.64)	0.188
Ownership	Self-owned	0.99(0.79,1.24)	0.944	1.28(1.14,1.44)	< 0.001	1.16(0.97,1.41)	0.111

^a Two level logistic regression models (city, individual). Odds ratios were adjusted for gender, current smoking, second hand smoke (SHS), home size, maternal occupation during pregnancy and dampness score.

^b The OR values were expressed per 0.001 unit increase for precipitation (mm).

^c The OR values were expressed per 1 unit increase for mean temperature (°C).

between water damage and eczema in southern cities (interaction *p* = 0.103). Moreover, there were stronger associations between mold odor (interaction *p* = 0.032), mold spots or damp stains (interaction *p* = 0.007), water damage (interaction *p* = 0.032) and allergic rhinitis in newer buildings (constructed after 2005). Furthermore, stronger associations were found between mold odor and eczema in self-owned dwellings (interaction *p* = 0.069), between water damage and asthma in self-owned dwellings (interaction *p* = 0.082) and between damp bed clothing and asthma in rented dwellings (interaction *p* = 0.073).

4. Discussion

Dampness and indoor mold were common in Chinese homes, especially in southern China. Mold odor was associated with asthma and allergic rhinitis. Mold spots or damp stains, water damage and damp bed clothing at home were associated with asthma, allergic rhinitis and eczema. Increased number of dampness indicators at home was associated with increased risk of asthma, allergic rhinitis and eczema. Window pane condensation in winter was associated with asthma, allergic rhinitis and eczema. Living in older buildings, constructed before 2005, was related to more asthma. Self-owned dwellings were associated with more allergic rhinitis. Participants living in suburban or rural areas had less asthma, allergic rhinitis and eczema. The effects of water damage and window pane condensation were stronger in southern China while the effect of mold odor was stronger in northern China. Moreover, stronger associations were found between dampness and mold and allergic rhinitis among participants living in newer buildings (constructed after 2005). Our study is one of the largest multicentre studies on asthma, allergic rhinitis and eczema among adults in relation to dampness and mold in the home environment.

Selection bias is one issue that should be considered in epidemiological studies. The questionnaire used in our study was sent to the caretakers of all children from randomly selected day care centres in eight cities across China. All parents (one parent per child) answered the questionnaire were included in the analyses. This study has a large sample size and a high response rate (75.0%). Furthermore, day care attendance in China is about 80%, with even higher attendance rate in urban areas (Norback et al., 2017a). The majority children in our study had no siblings as one child policy was still valid when the study performed. One limitation is that the participants were young parents (with children aged 1–8 y) and more than two third of them were mothers. This could lead to a selection bias related to gender. Males had more asthma in our study, which is opposite as compared to review articles (Janson et al., 2001; Leynaert et al., 2012), but not more allergic rhinitis and eczema. Another limitation is that our study was

undertaken mostly in urban areas. Thus, our study should be representative for parents of young children in urban China.

Information bias is another problem that can exist in epidemiological studies when participants should report exposure as well as symptoms. The data on annual precipitation and ambient temperature on city level were collected separately from different databases. Dampness problems as health risks have not been discussed in the public or media since the main concern is on outdoor air pollution. Other home environment characteristics answered by the participants (home size, house site, construction year and ownership) are less likely to be affected by participants' health condition. Moreover, different OR values were found for different home environment factors and asthma, allergic rhinitis and eczema. To summarize, we do not believe that information bias played an important role in our study. However, the cross-sectional design limits the possibility to draw conclusions on causality.

Confounding is another important issue in epidemiological studies. Socio-economic status (SES) has been considered to be a potential confounder. Unfortunately, we do not have family income data from our survey. Instead, we adjusted for home size and maternal occupation during pregnancy in the logistic regression models. One previous study from USA demonstrated that home size was a proxy variable of family income (Juhn et al., 2011). Moreover, data from the city of Tianjin in China found that a larger home size was associated with a higher family income (Norback et al., 2018). One European study found that dampness was more common reported by manual workers as compared to managerial/professional workers (Norback et al., 2017b).

Our study has several strengths. First of all, it is a large multicentre study included eight cities across China. Moreover, we included both climate data and many different home environment factors in the analyses. There are also some limitations. The participants included in our study were young parents. There was no information on age for the male participants and no questions on family history of allergic disorders. The health questions did not specify if the diseases were diagnosed by any doctor. Finally, the cross-sectional design limited the possibility to draw conclusions on causality.

Few participants (1.6%) had asthma in our study. Similar results were found in two previous Chinese studies performed about the same period as our study (Ding et al., 2017; Zhang et al., 2015). One national study reported that 1.5% urban adults across China had mild asthma (Ding et al., 2017). The other study found that 1.8% adults in Shanghai had physician diagnosed asthma (Zhang et al., 2015). Our study found that 6.6% had allergic rhinitis. This is lower as compare to two other Chinese multicentre studies on adult allergic rhinitis. One study including 11 major cities in China found that the prevalence of allergic

rhinitis among adults ranged from 8.7% to 24.1% (Zhang et al., 2009). The other study performed in 18 major cities reported that the prevalence of adult allergic rhinitis ranged from 9.6% to 23.9% (Wang et al., 2016). This can be due to different definition of allergic rhinitis, as our study asked if the participants had a history of allergic rhinitis. However, the other two Chinese studies used the ISAAC definition of allergic rhinitis: rhinitis symptoms (sneezing, runny, blocked or itchy nose) in the past 12 months when not having a cold (Asher et al., 2006). Few studies have investigated allergic eczema/dermatitis among adults. Eczema (2.2%) was uncommon in our study. Our data on eczema is in agreement with one recent review concluding that atopic dermatitis/eczema prevalence was between 1 and 3% among adults (Deckert et al., 2014).

Our study showed consistent associations between dampness and mold in homes and asthma, allergic rhinitis and eczema in adults. Moreover, increased number of dampness indicators (higher dampness score) were related to increased risk OR values for asthma, allergic rhinitis and eczema, indicating a dose-response relationship. A similar dampness index has been applied in previous studies (Norback et al., 2013; Zhang et al., 2019; Wang et al., 2014). Few previous studies among adults were available. Studies from Nordic countries (Sweden, Finland and Norway) (Norback et al., 1999; Koskinen et al., 1999; Kilpelainen et al., 2001; Skorge et al., 2005) have reported associations between dampness in dwellings and asthma/asthma symptoms. A multicentre study from Europe found that dampness at home was related to asthma onset among adults (Norback et al., 2013). Associations between dampness in dwellings and adult rhinitis were found in Sweden (Engvall et al., 2001), Finland (Koskinen et al., 1999; Kilpelainen et al., 2001; Pirhonen et al., 1996) and China (Zhang et al., 2019). We found only one study from Finland reported positive association between dampness in dwellings and atopic eczema in adults (Kilpelainen et al., 2001). Moreover, mold odor was related to adult asthma and allergic rhinitis in our study, this is in agreement with previous studies from Sweden (Engvall et al., 2001; Norback et al., 2014) and USA (Shiue, 2015).

Window pane condensation in winter was associated with asthma, allergic rhinitis and eczema in our study. Window pane condensation indoor in winter can be a sign of insufficient ventilation and high air humidity in a cold climate. Studies from Sweden and United Kingdom reported that window pane condensation was related to high relative air humidity and higher levels of house dust mite allergens in dust (Emenius et al., 2000; Luczynska et al., 1998). One Swedish study reported that window pane condensation in winter at home was a risk factor for onset of asthma symptoms among Swedish pilots (Fu et al., 2016). One Japanese study among university students found that window pane condensation at home was associated with wheeze symptoms (Takaoka and Norback, 2011). Moreover, window pane condensation at home has been shown to be related to rhinitis symptoms in China (Zhang et al., 2019) and Japan (Saijo et al., 2009). We found no previous published studies on window pane condensation and adult eczema.

Living in older buildings, constructed before 2005, was a risk factor for asthma. Older buildings are usually in a poorer condition as compared to newer buildings in China, e.g. can have more dirt and less ventilation. Moreover, self-owned dwellings were associated with allergic rhinitis in our study. We have no clear explanation to this finding but in our study, self-owned dwellings were associated with newer buildings and more window pane condensation in winter. Chemical emissions could be higher in new buildings and tight buildings (indicated by signs of window pane condensation). Smoking and SHS were both related to less allergic rhinitis in our study. Selection effects could be the explanation for the results. As shown by reviews including many articles, smoking/SHS were associated with increased risk of asthma/rhinitis among adults (Jayes et al., 2016; Hur et al., 2014).

Living in suburban/rural area was associated less asthma, allergic rhinitis and eczema in our study. We found that dwellings from less

urbanized areas (suburban and rural areas) had more mold odor, mold spots or damp stains and damp bed clothing. The significant associations remained for asthma, allergic rhinitis and eczema when adjusting dampness score in the models, with even lower odds ratios for asthma (OR = 0.45 vs. OR = 0.48), allergic rhinitis (OR = 0.24 vs. OR = 0.37) and eczema (OR = 0.66 vs. OR = 0.75). This indicates that differences in dampness or indoor mold between homes in urban, suburban and rural areas do not explain our observed associations between degree of urbanization and health. Many previous articles have found similar results showing that lower degree of urbanization in relation to less allergic disorders (Timm et al., 2015; Son et al., 2015; Elholm et al., 2016; Braback et al., 2004).

Our study found that asthma was more common among males. This is inconsistent with review articles reporting a female predominance of asthma among adults (Janson et al., 2001; Leynaert et al., 2012). The reason is unclear. Occupation exposure among Chinese males could be higher than females. We found that females had more eczema, which is in agreement with previous studies reporting that adult atopic dermatitis is more common among younger women (Katsarou and Armenaka, 2011; Silvestre Salvador et al., 2017).

Moreover, we found stronger associations between window pane condensation, water damage and allergic rhinitis/eczema in southern cities. Dampness and mold are more common in dwellings especially in southern China which often has a warm and humid climate. This indicates that climate may modify health associations. It can be important to study health associations in different subgroups concerning different climate zones. Moreover, our study found stronger associations between dampness and mold and allergic rhinitis in newer buildings. Other indoor pollutions, e.g. chemical emission in newly built dwellings could have modified the health associations with dampness.

5. Conclusions

Dampness and mold and window pane condensation at home can be risk factors for asthma, allergic rhinitis or eczema among adults. Living in older buildings can be a risk factor for adult asthma and allergic rhinitis. Living in less urbanized areas can be protective for asthma, allergic rhinitis and eczema. High ambient temperature and precipitation can influence eczema, linked to increased risk of dampness and mold in a warmer climate. It is important to avoid dampness and mold in Chinese homes, especially in southern China with a warm and humid climate where dampness and mold are more common in dwellings.

Declaration of Competing Interest

None.

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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.2019.104910>.

References

- Asher, M.I., Montefort, S., Björkstén, B., Lai, C.K., Strachan, D.P., Weiland, S.K., Williams, H., 2006. Worldwide time trends in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and eczema in childhood: ISAAC phases one and three repeat multicountry cross-sectional surveys. *Lancet* 368, 733–743.
- Baiz, N., Annesi-Maesano, I., 2012. Is the asthma epidemic still ascending? *Clin. Chest Med.* 33, 419–429.

- Bjerg, A., Ekerljung, L., Middelvel, R., Dahlen, S.E., Forsberg, B., Franklin, K., Larsson, K., Lotvall, J., Olafsdottir, I.S., Toren, K., et al., 2011. Increased prevalence of symptoms of rhinitis but not of asthma between 1990 and 2008 in Swedish adults: comparisons of the ECRHS and GA(2)LEN surveys. *PLoS One* 6, e16082.
- Braback, L., Hjert, A., Rasmussen, F., 2004. Trends in asthma, allergic rhinitis and eczema among Swedish conscripts from farming and non-farming environments. A nationwide study over three decades. *Clin. Exp. Allergy* 34, 38–43.
- Chiesa Fuxench, Z.C., 2017. Atopic dermatitis: disease background and risk factors. *Adv. Exp. Med. Biol.* 1027, 11–19.
- Deckert, S., Kopkow, C., Schmitt, J., 2014. Nonallergic comorbidities of atopic eczema: an overview of systematic reviews. *Allergy* 69, 37–45.
- Ding, B., DiBonaventura, M., Karlsson, N., Ling, X., 2017. A cross-sectional assessment of the prevalence and burden of mild asthma in urban China using the 2010, 2012, and 2013 China National Health and Wellness Surveys. *J. Asthma* 54, 632–643.
- Dong, G.H., Qian, Z.M., Wang, J., Trevathan, E., Ma, W., Chen, W., Xaverius, P.K., Buckner-Petty, S., Ray, A., Liu, M.M., et al., 2013. Residential characteristics and household risk factors and respiratory diseases in Chinese women: the Seven Northeast Cities (SNEC) study. *Sci. Total Environ.* 463–464, 389–394.
- Eichenfield, L.F., Tom, W.L., Chamlin, S.L., Feldman, S.R., Hanifin, J.M., Simpson, E.L., Berger, T.G., Bergman, J.N., Cohen, D.E., Cooper, K.D., et al., 2014. Guidelines of care for the management of atopic dermatitis: section 1. Diagnosis and assessment of atopic dermatitis. *J. Am. Acad. Dermatol.* 70, 338–351.
- Elholm, G., Linneberg, A., Husemoen, L.L., Omland, O., Gronager, P.M., Sigsgaard, T., Schlunssen, V., 2016. The Danish urban-rural gradient of allergic sensitization and disease in adults. *Clin. Exp. Allergy* 46, 103–111.
- Emenius, G., Korsgaard, J., Wickman, M., 2000. Window pane condensation and high indoor vapour contribution - markers of an unhealthy indoor climate? *Clin. Exp. Allergy* 30, 418–425.
- Engvall, K., Norrby, C., Norback, D., 2001. Asthma symptoms in relation to building dampness and odour in older multifamily houses in Stockholm. *Int J Tuberc Lung Dis* 5, 468–477.
- Fan, X.J., Yang, C., Zhang, L., Fan, Q., Li, T., Bai, X., Zhao, Z.H., Zhang, X., Norback, D., 2017. Asthma symptoms among Chinese children: the role of ventilation and PM10 exposure at school and home. *Int J Tuberc Lung Dis* 21, 1187–1193.
- Fisk, W.J., Lei-Gomez, Q., Mendell, M.J., 2007. Meta-analyses of the associations of respiratory health effects with dampness and mold in homes. *Indoor Air* 17, 284–296.
- Fu, X., Lindgren, T., Wieslander, G., Janson, C., Norback, D., 2016. Respiratory illness and allergy related to work and home environment among commercial pilots. *PLoS One* 11, e0164954.
- GINA Report 2017, Global Strategy for Asthma Management and Prevention [<http://ginasthma.org>].
- Heinrich, J., 2011. Influence of indoor factors in dwellings on the development of childhood asthma. *Int. J. Hyg. Environ. Health* 214, 1–25.
- Hur, K., Liang, J., Lin, S.Y., 2014. The role of secondhand smoke in allergic rhinitis: a systematic review. *Int Forum Allergy Rhinol* 4, 110–116.
- Jaakkola, M.S., Quansah, R., Hugg, T.T., Heikkinen, S.A., Jaakkola, J.J., 2013. Association of indoor dampness and molds with rhinitis risk: a systematic review and meta-analysis. *J. Allergy Clin. Immunol.* 132, 1099–1110 (e1018).
- Janson, C., Anto, J., Burney, P., Chinn, S., de Marco, R., Heinrich, J., Jarvis, D., Kuenzli, N., Leynaert, B., Luczynska, C., et al., 2001. The European Community respiratory health survey: what are the main results so far? European Community respiratory health survey II. *Eur. Respir. J.* 18, 598–611.
- Jayes, L., Haslam, P.L., Gratiou, C.G., Powell, P., Britton, J., Vardavas, C., Jimenez-Ruiz, C., Leonardi-Bee, J., 2016. SmokeHaze: systematic reviews and meta-analyses of the effects of smoking on respiratory health. *Chest* 150, 164–179.
- Juhn, Y.J., Beebe, T.J., Finnie, D.M., Sloan, J., Wheeler, P.H., Yawn, B., Williams, A.R., 2011. Development and initial testing of a new socioeconomic status measure based on housing data. *J. Urban Health* 88, 933–944.
- Katsarou, A., Armenaka, M., 2011. Atopic dermatitis in older patients: particular points. *J. Eur. Acad. Dermatol. Venereol.* 25, 12–18.
- Kilpelainen, M., Terho, E.O., Helenius, H., Koskenvuo, M., 2001. Home dampness, current allergic diseases, and respiratory infections among young adults. *Thorax* 56, 462–467.
- Koskinen, O.M., Husman, T.M., Meklin, T.M., Nevalainen, A.I., 1999. The relationship between moisture or mould observations in houses and the state of health of their occupants. *Eur. Respir. J.* 14, 1363–1367.
- Lai, C.K., Beasley, R., Crane, J., Foliaki, S., Shah, J., Weiland, S., 2009. Global variation in the prevalence and severity of asthma symptoms: phase three of the International Study of Asthma and Allergies in Childhood (ISAAC). *Thorax* 64, 476–483.
- Leynaert, B., Sunyer, J., Garcia-Esteban, R., Svanes, C., Jarvis, D., Cerveri, I., Dratva, J., Gislason, T., Heinrich, J., Janson, C., et al., 2012. Gender differences in prevalence, diagnosis and incidence of allergic and non-allergic asthma: a population-based cohort. *Thorax* 67, 625–631.
- Lu, C., Deng, Q., Li, Y., Sundell, J., Norback, D., 2016. Outdoor air pollution, meteorological conditions and indoor factors in dwellings in relation to sick building syndrome (SBS) among adults in China. *Sci. Total Environ.* 560–561, 186–196.
- Luczynska, C., Sterne, J., Bond, J., Azima, H., Burney, P., 1998. Indoor factors associated with concentrations of house dust mite allergen, Der p 1, in a random sample of houses in Norwich, UK. *Clin Exp Allergy* 28, 1201–1209.
- Lundback, B., Backman, H., Lotvall, J., Ronmark, E., 2016. Is asthma prevalence still increasing? *Expert Rev Respir Med* 10, 39–51.
- de Marco, R., Cappa, V., Accordini, S., Rava, M., Antonicelli, L., Bortolami, O., Braggion, M., Bugiani, M., Casali, L., Cazzoletti, L., et al., 2012. Trends in the prevalence of asthma and allergic rhinitis in Italy between 1991 and 2010. *Eur. Respir. J.* 39, 883–892.
- McNally, N.J., Williams, H.C., Phillips, D.R., 2001. Atopic eczema and the home environment. *Br. J. Dermatol.* 145, 730–736.
- Mendell, M.J., 2007. Indoor residential chemical emissions as risk factors for respiratory and allergic effects in children: a review. *Indoor Air* 17, 259–277.
- Norback, D., Bjornsson, E., Janson, C., Palmgren, U., Boman, G., 1999. Current asthma and biochemical signs of inflammation in relation to building dampness in dwellings. *Int J Tuberc Lung Dis* 3, 368–376.
- Norback, D., Wieslander, G., Nordstrom, K., Walinder, R., 2000. Asthma symptoms in relation to measured building dampness in upper concrete floor construction, and 2-ethyl-1-hexanol in indoor air. *Int J Tuberc Lung Dis* 4, 1016–1025.
- Norback, D., Zock, J.P., Plana, E., Heinrich, J., Svanes, C., Sunyer, J., Kunzli, N., Villani, S., Olivieri, M., Soon, A., Jarvis, D., 2013. Mould and dampness in dwelling places, and onset of asthma: the population-based cohort ECRHS. *Occup. Environ. Med.* 70, 325–331.
- Norback, D., Lampa, E., Engvall, K., 2014. Asthma, allergy and eczema among adults in multifamily houses in Stockholm (3-HE study)—associations with building characteristics, home environment and energy use for heating. *PLoS One* 9, e112960.
- Norback, D., Lu, C., Zhang, Y., Li, B., Zhao, Z., Huang, C., Zhang, X., Qian, H., Sundell, J., Deng, Q., 2017a. Common cold among pre-school children in China - associations with ambient PM10 and dampness, mould, cats, dogs, rats and cockroaches in the home environment. *Environ. Int.* 103, 13–22.
- Norback, D., Zock, J.P., Plana, E., Heinrich, J., Fischer, C., Jacobsen Bertelsen, R., Sunyer, J., Kunzli, N., Villani, S., Olivieri, M., et al., 2017b. Building dampness and mold in European homes in relation to climate, building characteristics and socio-economic status: the European Community Respiratory Health Survey ECRHS II. *Indoor Air* 27, 921–932.
- Norback, D., Lu, C., Wang, J., Zhang, Y., Li, B., Zhao, Z., Huang, C., Zhang, X., Qian, H., Sun, Y., et al., 2018. Asthma and rhinitis among Chinese children - indoor and outdoor air pollution and indicators of socioeconomic status (SES). *Environ. Int.* 115, 1–8.
- Odiambo, J.A., Williams, H.C., Clayton, T.O., Robertson, C.F., Asher, M.I., 2009. Global variations in prevalence of eczema symptoms in children from ISAAC phase three. *J. Allergy Clin. Immunol.* 124 (e1223), 1251–1258.
- Ozdoganoglu, T., Songu, M., 2012. The burden of allergic rhinitis and asthma. *Ther. Adv. Respir. Dis.* 6, 11–23.
- Pirhonen, I., Nevalainen, A., Husman, T., Pekkanen, J., 1996. Home dampness, moulds and their influence on respiratory infections and symptoms in adults in Finland. *Eur. Respir. J.* 9, 2618–2622.
- Quansah, R., Jaakkola, M.S., Hugg, T.T., Heikkinen, S.A., Jaakkola, J.J., 2012. Residential dampness and molds and the risk of developing asthma: a systematic review and meta-analysis. *PLoS One* 7, e47526.
- Sahlberg, B., Gunnbjornsdottir, M., Soon, A., Jogi, R., Gislason, T., Wieslander, G., Janson, C., Norback, D., 2013. Airborne molds and bacteria, microbial volatile organic compounds (MVOC), plasticizers and formaldehyde in dwellings in three North European cities in relation to sick building syndrome (SBS). *Sci. Total Environ.* 444, 433–440.
- Saijo, Y., Nakagi, Y., Ito, T., Sugioka, Y., Endo, H., Yoshida, T., 2009. Relation of dampness to sick building syndrome in Japanese public apartment houses. *Environ. Health Prev. Med.* 14, 26–35.
- Settipane, R.A., Charnock, D.R., 2007. Epidemiology of rhinitis: allergic and nonallergic. *Clin Allergy Immunol* 19, 23–34.
- Sharpe, R.A., Thornton, C.R., Tyrrell, J., Nikolaou, V., Osborne, N.J., 2015. Variable risk of atopic disease due to indoor fungal exposure in NHANES 2005–2006. *Clin. Exp. Allergy* 45, 1566–1578.
- Shiue, I., 2015. Indoor mildew odour in old housing was associated with adult allergic symptoms, asthma, chronic bronchitis, vision, sleep and self-rated health: USA NHANES, 2005–2006. *Environ. Sci. Pollut. Res. Int.* 22, 14234–14240.
- Shpakou, A., Brozek, G., Stryzhak, A., Neviartovich, T., Zejda, J., 2012. Allergic diseases and respiratory symptoms in urban and rural children in Grodno Region (Belarus). *Pediatr. Allergy Immunol.* 23, 339–346.
- Silvestre Salvador, J.F., Romero-Perez, D., Encabo-Duran, B., 2017. Atopic dermatitis in adults: a diagnostic challenge. *J. Invest Allergol Clin Immunol* 27, 78–88.
- Skorge, T.D., Eagan, T.M., Eide, G.E., Gulsvik, A., Bakke, P.S., 2005. Indoor exposures and respiratory symptoms in a Norwegian community sample. *Thorax* 60, 937–942.
- Son, J.Y., Kim, H., Bell, M.L., 2015. Does urban land-use increase risk of asthma symptoms? *Environ. Res.* 142, 309–318.
- Sundell, J., Levin, H., Nazaroff, W.W., Cain, W.S., Fisk, W.J., Grimsrud, D.T., Gyneltberg, F., Li, Y., Persily, A.K., Pickering, A.C., et al., 2011. Ventilation rates and health: multidisciplinary review of the scientific literature. *Indoor Air* 21, 191–204.
- Takaoka, M., Norback, D., 2011. The home environment of Japanese Female University students - association with respiratory health and allergy. *Indoor and Built Environment* 20, 369–376.
- Timm, S., Frydenberg, M., Janson, C., Campbell, B., Forsberg, B., Gislason, T., Holm, M., Jogi, R., Omenaas, E., Sigsgaard, T., et al., 2015. The urban-rural gradient in asthma: a population-based study in northern Europe. *Int. J. Environ. Res. Public Health* 13.
- Ukawa, S., Araki, A., Kanazawa, A., Yuasa, M., Kishi, R., 2013. The relationship between atopic dermatitis and indoor environmental factors: a cross-sectional study among Japanese elementary school children. *Int. Arch. Occup. Environ. Health* 86, 777–787.
- Wang, J., Li, B., Yu, W., Yang, Q., Wang, H., Huang, D., Sundell, J., Norback, D., 2014. Rhinitis symptoms and asthma among parents of preschool children in relation to the home environment in Chongqing, China. *PLoS One* 9, e94731.
- Wang, X.D., Zheng, M., Lou, H.F., Wang, C.S., Zhang, Y., Bo, M.Y., Ge, S.Q., Zhang, N., Zhang, L., Bachert, C., 2016. An increased prevalence of self-reported allergic rhinitis in major Chinese cities from 2005 to 2011. *Allergy* 71, 1170–1180.
- Weinmayr, G., Gehring, U., Genuneit, J., Buchele, G., Kleiner, A., Siebers, R., Wickens, K., Crane, J., Brunekreef, B., Strachan, D.P., 2013. Dampness and moulds in relation to respiratory and allergic symptoms in children: results from phase two of the

- International Study of Asthma and Allergies in Childhood (ISAAC phase two). *Clin. Exp. Allergy* 43, 762–774.
- WHO, 2009. In WHO Guidelines for Indoor Air Quality: Dampness and Mould. World Health Organization, Geneva.
- Zhang, Y., Zhang, L., 2014. Prevalence of allergic rhinitis in China. *Allergy Asthma Immunol Res* 6, 105–113.
- Zhang, L., Han, D., Huang, D., Wu, Y., Dong, Z., Xu, G., Kong, W., Bachert, C., 2009. Prevalence of self-reported allergic rhinitis in eleven major cities in China. *Int. Arch. Allergy Immunol.* 149, 47–57.
- Zhang, Y.P., Li, B.Z., Huang, C., Yang, X., Qian, H., Deng, Q.H., Zhao, Z.H., Li, A.G., Zhao, J.N., Zhang, X., et al., 2013. Ten cities cross-sectional questionnaire survey of children asthma and other allergies in China. *Chin. Sci. Bull.* 58, 4182–4189.
- Zhang, F., Hang, J., Zheng, B., Su, L., Christiani, D.C., 2015. The changing epidemiology of asthma in Shanghai, China. *J. Asthma* 52, 465–470.
- Zhang, X., Norback, D., Fan, Q., Bai, X., Li, T., Zhang, Y., Li, B., Zhao, Z., Huang, C., Deng, Q., et al., 2018. Dampness and mold in homes across China: associations with rhinitis, ocular, throat and dermal symptoms, headache and fatigue among adults. *Indoor Air*.
- Zhang, X., Norback, D., Fan, Q., Bai, X., Li, T., Zhang, Y., Li, B., Zhao, Z., Huang, C., Deng, Q., et al., 2019. Dampness and mold in homes across China: associations with rhinitis, ocular, throat and dermal symptoms, headache and fatigue among adults. *Indoor Air* 29, 30–42.
- Zock, J.P., Jarvis, D., Luczynska, C., Sunyer, J., Burney, P., 2002. Housing characteristics, reported mold exposure, and asthma in the European Community Respiratory Health Survey. *J. Allergy Clin. Immunol.* 110, 285–292.

Supplement

Table S1. Data on construction year (%), stratified for ownership ($n=40279$).

Category	Subcategory	Self-owned (%)	Rented (%)	p^a
Construction year	After 2005	76.2	23.8	<0.001
	2001-2005	77.4	22.6	
	1991-2000	59.1	40.9	
	Before 1991	40.2	59.8	

^a Chi-square test.

Table S2. Associations between climate, northern/southern cities, house site, construction year, ownership and self-reported asthma, allergic rhinitis and eczema among young parents by two level logistic regression models OR (95%CI) ^a (n=40279).

Category	Subcategory	Asthma	<i>p</i>	Allergic rhinitis	<i>p</i>	Eczema	<i>p</i>
Precipitation ^b		1.32(0.88,1.99)	0.176	0.94(0.47,1.85)	0.851	2.39(1.21,4.72)	0.013
Mean temperature ^c		1.03(0.99,1.07)	0.189	0.98(0.91,1.05)	0.543	1.10(1.02,1.18)	0.016
Northern/southern cities	Northern	1.00		1.00		1.00	
	Southern	1.29(0.95,1.76)	0.105	0.92(0.53,1.57)	0.753	1.90(1.06,3.40)	0.031
House site	Urban	1.00		1.00		1.00	
	Suburban	0.48(0.38,0.62)	<0.001	0.58(0.51,0.65)	<0.001	0.75(0.62,0.90)	0.002
	Rural	0.63(0.37,1.04)	0.074	0.37(0.26,0.55)	<0.001	0.65(0.40,1.07)	0.092
Construction year	After 2005	1.00		1.00		1.00	
	2001-2005	1.49(1.14,1.93)	0.003	1.11(0.98,1.25)	0.094	1.27(1.03,1.50)	0.026
	1991-2000	1.57(1.19,2.05)	0.001	1.11(0.98,1.26)	0.098	1.30(1.04,1.62)	0.022
	Before 1991	1.71(1.27,2.32)	<0.001	1.22(1.05,1.41)	0.010	1.43(1.11,1.83)	0.006
Ownership	Self-owned	1.03(0.86,1.24)	0.747	1.25(1.13,1.37)	<0.001	1.04(0.89,1.20)	0.592

^a Two level logistic regression models (city, individual). Odds ratios were adjusted for gender, current smoking, second hand smoke (SHS), home size and maternal occupation during pregnancy.

^b The OR values were expressed per 0.001 unit increase for precipitation (mm).

^c The OR values were expressed per 1 unit increase for mean temperature (°C).