Outdoor air pollution, meteorological conditions and indoor factors in dwellings in relation to sick building syndrome (SBS) among adults in China

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Abstract

Indoor environment is associated with the sick building syndrome (SBS), but little is known about the contribution of outdoor air pollution and meteorological conditions to SBS. We studied associations between outdoor air pollution, meteorological parameters and selected indoor exposure and building characteristics at home and weekly SBS symptoms in a standardized questionnaire study among 3,485 randomly selected adults in China. Outdoor factors included particulate matters with diameter less than 10 μm (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), outdoor temperature (T), relative air humidity (RH), and wind speed (WS) during last three months. Multiple logistic regression was applied calculating odds ratios (OR) with 95% confidence interval (95% CI). Asthma or allergic rhinitis (atopy) was associated with all types of SBS symptoms except fatigue. Indoor factors played a major role in SBS symptoms. Mold/dampness on the floor/ceiling was associated with fatigue OR=1.60 (1.11-2.30) and headache OR=1.80 (1.07-3.04). Moldy odor was associated with fatigue OR=1.59 (1.07-2.37) and dermal symptoms OR=1.91 (1.21-3.02). Window pane condensation in winter was associated with fatigue OR=1.73 (1.30-2.31) and throat symptoms OR=1.53 (1.01-2.31). Damp bed clothing was related with throat symptom OR=1.62 (1.09-2.40). Home redecoration was associated with fatigue OR=1.49 (1.07-2.06). Frequent window opening was associated with less nose symptoms OR=0.54 (0.36-0.82) and mechanical ventilation in the bathroom reduced dermal symptoms OR=0.66 (0.44-0.99). Females were more susceptible to redecoration and window pane condensation than men. No associations with SBS were observed for outdoor air pollutants or meteorological parameters in the final models combining indoor and outdoor factors, although SO_2 , T, and RH were associated with some SBS symptoms (fatigue, eyes and nose symptoms) in the separate outdoor models. In conclusion, indoor mold/dampness, air pollution from redecoration and poorer ventilation conditions in dwellings can be risk factors for SBS symptoms in an adult Chinese population, especially among females.

1. Introduction

Sick building syndrome (SBS) was defined as certain medical symptoms experienced by occupants in specific indoor environments, which includes symptoms of headache, fatigue and irritation in upper respiratory tract, nose throat, eyes, hand and or facial skin (WHO 1983; Redlich et al. 1997). People in industrialized countries spend about 90% of their life indoors, mostly at home, which may result in a high risk of SBS in general population. SBS is suggested to be associated with personal and environmental factors (Norback 2009). Although some personal factors, such as female gender, history of atopy/allergic disorders, and smoking status, have been widely reported for more SBS due to higher sensitivity (Björnsson et al. 1998; Brasche et al. 2001; Lim et al. 2015; Molina et al. 1993; Runeson et al. 2006), the prevalent complains of SBS from general populations (i.e. residences) are more likely to be related with the environmental issues.

Indoor environmental factors in relation to SBS have been largely investigated, especially for office environment. A number of studies have found some important indoor factors that are closely associated with SBS, such as building dampness, ventilation flow, volatile organic compounds (VOCs), mold or microbial contaminations, and indoor climate factors (room temperature and relative humidity) (Bakke et al. 2008; Brinke et al. 1998; Fang 2004; Jaakkola et al. 1991; Molhave et al. 1993; Norback and Nordstrom 2008; Reinikainen and Jaakkola 2001; Sundell et al. 2011; Teeuw et al. 1994; Wolkoff 2008; Zhang et al. 2012). Most previous studies on sick building syndrome (SBS) have dealt with symptoms among office workers (Apter et al. 1994), but only a few studies have addressed SBS in relation to home environment. (Araki et al. 2010; Bornehag et al. 2003; Kanazawa et al. 2010; Kishi et al. 2009; Sahlberg et al. 2010; Sahlberg et al. 2013; Saijo et al. 2009; Takigawa et al. 2010). In the office environment, SBS may have important implications affecting productivity. However, since we spend most of our time at home the influence of the home environment on SBS deserves further attention (Norback 2009). A few home environment studies with respect to SBS have been recently performed in China (Wang et al. 2013a; Wang et al. 2013b), but more investigations is needed since there is a big difference in home environments and climate among different areas in China.

Most previous studies on SBS have focused on indoor environment without considering outdoor air pollution or climate factors. However, with the rapid development of economy and urbanization during past decades, urban air pollution has been more and more serious and prevailed in many Chinese cities. In addition, extreme climate (i.e. heat waves) can be more prevalent due to global warming (Luber and McGeehin 2008), which may cause a heavy burden and serious health risk in general population (Epstein 2000; McMichael et al. 2006; Patz et al. 2005). Since the outdoor exposure may influence the indoor environment, the role of outdoor air pollution and meteorological conditions for SBS in dwellings should not be neglected. However, a few studies from China have examined associations between outdoor factors and SBS. A longitudinal study in China investigated associations between outdoor air pollution in schools (SO_2 , NO_2 , O_3 , and PM_{10}) and SBS among pupils, and found that outdoor air pollution could increase the prevalence and incidence of SBS and decrease the remission rate (Zhang et al. 2014). However, there is no SBS study in relation to domestic exposure to outdoor air pollution in China, which warrants to be investigated.

In the present study, we hypothesized that there is associations between outdoor air pollution (PM_{10} , SO_2 , and NO_2), climate factors (T, RH, and WS) and indoor exposures

(mold/dampness, renovations, and ventilation conditions) and adult's SBS symptoms. This was investigated in a part of a large national multi-centre study "China, Children, Homes, Health (CCHH)" (Zhang et al. 2013). Our aim was to investigate: (1) Whether outdoor air pollution and meteorological parameters exposure during past three months is associated with weekly SBS symptoms in adults (2) Which indoor exposures in dwellings are associated with SBS symptoms? (3) Whether there is interaction between gender and environmental exposures in relation to SBS symptoms.

2. Material and methods

2.1 Ethics statement

We sent an information letter to the parents' children's kindergarten addresses, along with the questionnaire, stating that if they answered and returned the questionnaire, they were thereby given their informed consent. The nature and possible consequences of the study were explained to the subjects before the study began. The questionnaire study and the exposure measurements in the kindergartens had been granted permission by the principal of each kindergarten and the teachers of each kindergarten involved in the study. The study protocol and the informed consent procedure were reviewed and approved by the Ethical Committee of the Medical Faculty of Central South University, Changsha, China which did not require a written consent since the study did not include any clinical tests. In addition, the study was approved by the health department and school board of each kindergarten.

2.2 Study population

The present study is a part of the multi-cities project (CCHH) study on asthma and allergies among preschool children in relation to the home environment in China. The participants in this study are the parents who filled in the questionnaire about their own health and the child's health (one person per family). The questionnaires asked about sick building syndrome (SBS) symptoms for the person who filled the questionnaire, as well as their gender, smoking habits and asthma/allergy (atopy). In this publication we do not use any data about the child. The questionnaire was mostly answered by the child's parents, but in a few cases by grandparents, or others persons. We have restricted our study to the parents.

The study was conducted between September 2011 and January 2012 in 36 kindergartens in Changsha, the capital city of Hunan Province in south-central China, having a population of 7.22 million inhabitants and covering an area of 1,909 km². Changsha has a humid subtropical climate with an annual mean temperature of 17 °C, and a monthly mean of 4.6 °C in January and 29 °C in July. The four seasons are distinct. The summers are very hot and winter is chilly. Autumn is the driest season. There are five main districts in Changsha (Furong, Kaifu, Tianxin, Yuhua, and Yuelu). We randomly selected 36 kindergartens from all five districts, which would like to participate in our survey, and these kindergartens were almost evenly distributed in Changsha. Then we randomly selected children from each kindergarten. The number of the questionnaires sent to the kindergartens was based on the total number of children in each kindergarten, China. The percentage of distributed questionnaires were 20% for Furing distict, 28% for Kaifu, 14% for Tianxin, 16% for Yuhua and 21% for Yuelu. Detailed information and map of the location of the 36 kindergartens has been previously

published (Deng et al. 2015).

A Chinese version of the standard questionnaire designed by the International Study of Asthma and Allergies in Childhood (Asher et al. 2006), with some changes to address housing and cultural characteristics in China, was administered to collect information on health status of children and family members. Each participant was asked to write the date when the questionnaire was answered. A total of 4,988 questionnaires were randomly distributed to the parents whose children were in 36 participating kindergartens (Deng et al. 2015). Parents or other guardians were instructed to complete the questionnaire and to return it to kindergartens within one week. We received 3,897 completed questionnaires and the overall response rate was 78%. We first excluded the questionnaires filled by grandmothers (n=104), grandfathers (n=89), others (n=23), and those without information on who answered the questionnaire (n=110), and thus selected 3571 questionnaires filled by the child's father (n=831) or mother (n=2740). Then, we excluded 96 subjects who did not answer the questions on their children's sex (n=10) and age (n=86) since they were not considered as reliable. Finally, 3,485 parents (one parent per child aged 1-8 years old) were included in this study.

2.3 Assessment of sick building syndrome (SBS) symptoms

The symptoms of sick building syndrome (SBS) during past 3 months included three groups: general symptoms (fatigue, and headache); mucosal symptoms (itching, burning or irritation of the eyes, irritating, stuffy or runny nose, and hoarse, dry throat); dermal symptoms (any symptom among dry or flushed facial skin, scaling/itching scalp or ears, and hands dry, itching, red skin). There were three options to choose for each symptom: weekly/sometimes/never. Any SBS symptom was defined as the subjects who reported an occurrence of weekly symptom.

2.4 Assessment of personal factors

Potential confounding variables obtained from the parent administered questionnaires included the parent's gender, current smoking, and history of atopy. Asthma and rhino-conjunctivitis are related to an atopic background, and thus the question asking "Have you ever been diagnosed as having asthma, or nose/eyes allergy by a doctor?" was used to define history of atopy in the present study.

2.5 Assessment of exposure to outdoor air pollutants and meteorological factors

We examined three pollutants, sulphur dioxide (SO₂), nitrogen dioxide (NO₂) and particles less than 10 micrometer (PM₁₀) to represent ambient air pollution in Changsha where SO₂ was used as an indicator of industry-related air pollution, NO₂ as traffic-related air pollution, and PM₁₀ as a surrogate of complex mixture of air pollutants (Kan et al. 2012). Daily 24-hour average ambient concentrations of PM₁₀, SO₂ and NO₂ were obtained from 7 municipal air pollution monitoring stations during the period from June to December, 2011, that is, a period that encompassed the periods for all the subjects in the present study. Measurements at the monitoring stations strictly followed the standard methods set by the State Environmental Protection Agency of China: PM₁₀ by a tapered element oscillating microbalance (TEOM1400, Rupprecht & Patashnick, USA), SO₂ by ultraviolet fluorescent method

(ML/EC9850, Ecotech, Australia) and NO₂ by the chemiluminescent method (ML/EC9841B, Ecotech, Australia). The detailed information of the monitoring stations and surveyed kindergartens was provided in our previous study (Deng et al. 2015).

We used an inverse distance weighted (IDW) method (Bell 2006; Marshall et al. 2008) to estimate the air pollution concentrations at the kindergartens based on the data at the monitoring stations. The concentration at each kindergarten was calculated by the concentrations at the closest four monitoring stations, with an inverse of the squared distance ($1/d^2$) used as the weighting function. At first, we used the available daily (24-h) average concentrations at 7 monitoring stations to obtain the daily mean concentrations at 36 kindergartens. Then the individual three months mean concentration of PM₁₀, SO₂ and NO₂ for each person was calculated, based on the date when the questionnaire was filled in (counting daily means 3 months back) for the particular kindergarten. The exposure of the subjects was calculated in terms of the air pollutant concentrations at their children's kindergartens, because parents usually enrolled their children in the kindergarten nearest to their home and hence exposure at home was considered to be the same as that at the kindergarten.

We selected three meteorological parameters, temperature (T), relative humidity (RH), and wind speed (WS) to present the climate factors in this city. Daily meteorological data were obtained from the website of the Weather Underground (<http://wunderground.com>). There were only one monitoring station for meteorological parameters in the city. Individual mean values for T, RH and WS were calculated based on the date when the questionnaire was filled in (counting daily means 3 months back).

2.6 Assessment of exposure to indoor factors in the home environment

Indoor factors included four groups as follows, and the question regarding each factor was shown in Table S1:

- Building characteristics: building age and house size.
- Mold/dampness factors: mold/damp stains on floor/ceiling, moldy odor, dampness on bed/clothing, window pane condensation in winter, and water damage.

Furthermore, to address the dose-response relationships between symptoms and exposure to mold/dampness factors, a building dampness score (0-5) was constructed. Each “yes” or “frequently” responses to each factor was coded as “1”, and each “no” or “never/sometimes” response was coded as “0”. The total score was obtained by adding the score of above 5 factors together for each subject, and divided into four categories: 0 (no factor), 1 (1 factor), 2 (2 factors) and >2 (3, 4, and 5 factors).

In addition, another mold/dampness factor was also considered defined by “putting bedding in sunshine”. Putting bedding into sunshine is a Chinese habit aiming to reduce humidity in the bed. Not putting the bedding to sunshine was considered an indoor dampness factor but is not primarily a building factor.

- Indoor air pollution: new furniture, redecoration, and environmental tobacco smoke (ETS) at home.
- Ventilation factors: window opening habits, mechanical ventilation in kitchen, and exhaust fan in bathroom.

2.7 Statistical analysis

Firstly, we used multiple logistic regression models to evaluate the associations between SBS symptoms and outdoor air pollutants (PM₁₀, SO₂, and NO₂) and meteorological parameters (T, RH, and WS) by adjusting for personal factors (gender, current smoking and a history of atopy). We used both normal multiple logistic regression and multi-level multiple logistic regression. Two levels were used, individual level and kindergarten level. Secondly, we used multiple logistic regression models to examine the associations between SBS symptoms and indoor exposures including building characteristics (building age, and house size), indoor mold/dampness (mold/dampness stains on floor/ceiling, moldy odor, dampness on bed/clothing, putting bedding in sunshine, window pane condensation in winter, and water damage) and dampness score (score =0, 1, 2, and >2), indoor air pollution (new furniture, and redecoration at home), and indoor ventilation condition (window opening habits, mechanical ventilation in kitchen, and exhaust fan in bathroom). Thirdly, we used stepwise regression model to investigate the associations between SBS symptoms and all the outdoor and indoor factors to rank the effects of these factors. Then, we performed the final multiple regression models (final model) by using the combined personal factors and the significant factors analyzed in the stepwise model. Since results concerning outdoor factors were almost identical between logistic regression and multi-level logistic regression, we used normal logistic regression in the final models including indoor and outdoor factors. Finally, interactions between gender index and exposures to outdoor and indoor factors and were investigated by including an interaction term into the final model (Melén et al. 2004), which represents the differences in the estimated effects of factor exposure between the male and female gender.

We assess the association between each SBS symptom and air pollutants and meteorological parameters by per IQR increase in the exposure level. The group of dampness score = 0 was applied to reference, and the odds ratios of the groups of 1, 2, and >2 (2-5) dampness scores were analyzed. Results of the regression analysis were interpreted by odds ratio (OR) with 95% confidence interval (95% CI) where p value less than 0.05 was considered statistically significant. P values of interaction less than 0.1 was considered in the present study. All statistical analyses were performed by SPSS software (version 16.0) except multi-level logistic regression which was performed with STATA 13.0 statistical package.

3. Results

3.1 Personal characteristics and symptoms

A total of 76.8% of the participants were females, 12.8% were current smokers and 6.2% had a history of atopy (allergic asthma or allergic rhino-conjunctivitis). Most of the current smokers were males, 50.7% of the males but only 1.2% of the females were smokers ($p < 0.001$). Of 3,485 respondents, 489 (14.6%) reported weekly fatigue and 132 (4.2%) weekly headache. Mucosal and dermal symptoms were less common than general symptoms, with 102 (3.2%) reported for weekly eyes symptoms, 106 (3.4%) for weekly nose symptoms, 154 (4.8%) for weekly throat symptoms, and 137 (4.3%) for any weekly dermal symptoms. Table 1 shows the prevalence of each SBS symptom stratified by the personal factors. Females had more headache and eyes symptoms than males. Subjects with a history of atopy had higher prevalence of all the SBS symptoms as compared to those without atopy. However, no significant associations between subject's smoking habit and SBS symptoms were

observed except for a borderline significance for eyes symptom.

3.2 Descriptive data on outdoor air pollution and meteorological data

Table 2 summarizes the statistics of exposure levels of outdoor air pollution and meteorological parameters during past three months. The average individual exposures (mean $\pm$ SD) to PM₁₀, SO₂ and NO₂ were 80 $\pm$ 13 $\mu\text{g}/\text{m}^3$, 31 $\pm$ 5 $\mu\text{g}/\text{m}^3$, and 40 $\pm$ 5 $\mu\text{g}/\text{m}^3$, respectively. Interquartile range (IQR) of PM₁₀ was the largest, but the values for the other two pollutants were similar during exposure period. The average individual exposures to T, RH and WS were 25.2 $\pm$ 2.9 °C, 75.6 $\pm$ 1.3%, and 2.4 $\pm$ 1.5 m/s, and the IQR were 5 °C, 2%, and 0.83 m/s, respectively.

3.3 Descriptive data on indoor environment

Table 3 presents the statistics of exposure to indoor factors. Less than half of the participants lived in an older house with building age larger than 10 years; and one third of people lived in a home with an area $\geq 75 \text{ m}^2$. For indoor mold/dampness exposure, only a small groups' house appeared mold/damp stains on floor/ceiling, moldy odour, or water damage; less than half groups observed dampness on bed/clothing; half percentage of people found window pane condensation in winter; and most people like to put bedding in sunshine frequently to reduce mold/dampness. About one third of groups did not observe any signs of mold/dampness in their home; slight more than one third reported one sign and slightly less than one third reported more than one mold/dampness sign. For indoor air pollution exposure, slightly more than one third of families had installed new furniture since their children older than 1 year; only a small part of families had redecorated their house; and two thirds of families had residences who smoked at home. For indoor ventilation conditions, nearly two thirds of subjects opened windows frequently; and most people had mechanical ventilation in kitchen and exhaust fan in bathroom.

3.4 Correlation between outdoor air pollution and meteorological parameters

Table 4 showed Pearson correlations between air pollutants and meteorological parameters exposures during past three months calculated from the date when answered the questionnaire. Due to high correlation between T and RH, we adjusted for T and WS but not RH when investigating associations between air pollutants and SBS symptoms. Furthermore, in the regression models for meteorological conditions, we did not adjusted for air pollutants because of high correlations between air pollutants.

3.5 SBS symptoms in relation to outdoor factors

Table 5 provides effect estimates of SBS symptoms by per IQR increase of PM₁₀, SO₂, and NO₂ after adjusting for personal factors. Significant association was observed between outdoor SO₂ exposure and nose symptoms, with OR (95% CI) of 1.32 (1.01, 1.72). Outdoor T was positively associated with fatigue and eyes symptoms, whereas RH was negatively related with fatigue symptom.

3.6 Correlation between outdoor and indoor factors

Table 6 showed Pearson correlations between outdoor and indoor factors. SO₂ and T were selected to indicate outdoor air pollution and meteorological factors due to their relatively stronger associations with SBS symptoms. Due to low correlations of each factor among or between outdoor and indoor factors, we could include both indoor and outdoor factors in the models.

3.7 SBS-symptoms in relation to indoor factors

Table 7 provides the associations between indoor factors exposure and SBS symptoms. Subjects living in a house with older age or smaller size had lower risk of weekly fatigue than those living in a house with younger age or larger size. For mold/dampness factors, mold/dampness on floor/ceiling, moldy odour, and dampness on bed/clothing were positively associated with most of the symptoms; window pane condensation was related with fatigue and throat symptoms; and water damage was associated with eyes symptoms. We found that the habit of putting bedding in sunshine significantly decreased the risk of fatigue and nose symptoms. Moreover, people who lived in a home with more than one sign of mold/dampness (dampness score ≥ 2) were more likely to have SBS symptoms than those with one sign (dampness score =1) as compared to homes with no mold/dampness. For indoor air pollution, new furniture and redecoration was associated with increased risk of fatigue, and ETS exposure at home was mainly related with nose and throat symptoms. For ventilation condition, frequent opening windows significantly decreased the risk of fatigue, eyes, and nose symptoms compared to never/sometimes opening windows. The use of exhaust fan in bathroom significantly reduced the risk of dermal symptoms. However, no associations were observed between mechanical ventilation in kitchen and SBS symptoms.

3.8 SBS-symptoms in relation to outdoor and indoor factor in final models

Table 8 provides the associations between both outdoor and indoor factors and SBS symptoms. We observed associations mainly for indoor factors and SBS symptoms in the final models. Atopy was significantly associated with all SBS symptoms except fatigue, while no significant association was observed for gender and current smoking with any symptoms. In addition, history of atopy ranked as the top factor with an especially high Wald value for nose symptom (170.10). Mold/dampness on floor/ceiling was associated with general SBS symptoms including fatigue and headache ($p=0.012$ and 0.028 , respectively); moldy odor was related with fatigue and dermal symptoms ($p=0.021$ and 0.006 , respectively); window pane condensation in winter was associated with fatigue and throat symptoms ($p<0.001$ and 0.045 , respectively); and dampness on bed/clothing was related with throat symptom ($p=0.018$). Among indoor air pollution, redecoration exposure was associated with fatigue ($p=0.017$). Among indoor ventilation factors, frequent opening windows and the use of exhaust fan in the bathroom was negatively associated with nose symptoms ($p=0.004$) and dermal symptoms ($p=0.045$). However, we did not find any associations for outdoor air pollutants or meteorological parameters.

4. Discussion

The present study regarding associations between SBS symptoms in adults and both outdoor and indoor factors in dwellings showed that indoor factors, such as indoor mold/dampness, air pollution emitted from renovations, and ventilation, were associated with weekly SBS symptoms in general populations. A history of atopy had the strongest association with most SBS symptoms. Mold/dampness factors were associated with most SBS symptoms including fatigue, headache, throat, and dermal symptoms. Redecoration was associated with fatigue only. Ventilation factors including window opening habits and exhaust fan in bathroom were associated with nose and dermal symptoms. However, no significant associations with SBS symptoms were detected for outdoor air pollution or meteorological conditions. Moreover, our study indicate that females can be more sensitive than males to the effects of indoor redecoration and window pane condensation in winter with respect to fatigue and headache.

In our study, general symptoms were more common than mucosal and skin symptoms, which is consistent with another CCHH study from Chongqing, China (Wang et al. 2013a). The prevalence of general symptoms including weekly fatigue and headache in our study were about 1.7 and 2.2 times higher than those in their study. Prevalence of mucosal symptoms (itching/burning/irritation of eyes, irritating/stuffy/runny nose, and hoarse/dry throat) in our study were about 1.5 times higher than their study. In contrast, the prevalence of weekly dermal symptoms in our study (4.3%) was similar as in the Chongqing study (4.4%). In the present study, females had more headache, eyes, and nose symptoms than males. This result is inconsistent with other Chinese studies of both adults and high school pupils' SBS symptoms which showed only a small difference between genders (Wang et al. 2013a; Zhang et al. 2012).

This study, to our knowledge, is one of few studies investigating association between SBS symptoms and outdoor air pollution and climate factors. A strength of our study is that outdoor exposure levels, mean values for the 3 months recall period of the SBS questions, was calculated for each participant, based on information on when the questionnaire was answered as well as calculated air pollution levels for the particular kindergarten. A recent Chinese study regarding association between SBS and both outdoor air pollution and climate among pupils have found that outdoor SO₂ was positively associated with new onset of skin symptoms, while NO₂ and PM₁₀ were positively associated with new onset of skin, general and mucosal symptoms. We found positive associations between nose symptoms and SO₂ but the association was not significant in the final models adjusting for indoor factors.

Our finding that a history of asthma and allergies was strongly associated with most SBS symptoms is consistent with previous studies (Björnsson et al. 1998; Lim et al. 2015; Menzies et al. 1998; Molina et al. 1993; Runeson et al. 2006; Sahlberg et al. 2012). However, some studies did not find any association (Bakke et al. 2008; Gomzi et al. 2008). Significantly higher prevalence of SBS symptoms among subjects with atopy than those without atopy may be due to active allergic inflammation (Lim et al. 2015). We found gender differences for headache, eye symptoms and nose symptoms in the initial analysis but none of these gender differences were statistically significant in the final models. A Swedish study found that females had a higher prevalence of SBS symptoms than men but these differences were not statistically significant when adjusting for differences in allergy to nickel, non-specific airway hyperactivity and proneness to infections (Norbäck and Edling 1991). However, many studies have found that females have more SBS symptoms than men (e.g. Runeson et al. 2006;

Björnsson et al. 1998; Engvall et al. 2010; Jaakkola et al. 1991). It has been suggested that women suffer more SBS than men independent of personal, but most related to work and building factors (Brasche et al. 2001). However, the interaction analysis in our study indicated that females could be more susceptible to the effects of indoor redecoration and window pane condensation in winter on fatigue and headache symptoms respectively as compared to males, with ORs (95% CI) = 1.85 (1.28, 2.69) vs. 0.74 (0.35, 1.55) (interaction $p = 0.03$) and 1.75 (1.07, 2.85) vs. 0.69 (0.22, 2.14) (interaction $p = 0.09$) (data not shown in the tables).

About half of the homes were new, constructed the last 10 years, and most had an area of less than 75 m². Indoor mold and dampness was very common, 66% had at least one such sign. Dampness on bed clothing (56.3%) and window pane condensation in winter (51.5%) were most common while visible mold/damp stains (12.4%), moldy odor (11.8%) and water damage (10.5%) were less common. The habit to frequently put bed clothing in the sunshine was very common (60.3%). Putting bedding into sunshine is a Chinese habit aiming to reduce the humidity in the bed. Environmental tobacco smoke at home was very common, 66.8% reported that tobacco smoking occurred indoors. In addition new furniture, which can emit formaldehyde, was very common (38.6%) as well as recent redecoration of the home (19.2%). The most common method to increase the ventilation was frequent window opening (63.5%) but exhaust fan in the bathroom was very common as well (79.8%).

Our findings that indoor mold/dampness factors, including mold/dampness on floor/ceiling, moldy odour, window pane condensation in winter, dampness on bed/clothing, and putting bed in sunshine, were associated with most SBS symptoms is consistent with previous studies regarding associations between dampness factors and SBS symptoms. A number of studies found that an increased risk of SBS was associated with visible mold, mould/damp spots, and moisture problem in floors in dwellings (Bornehag et al. 2003; Kishi et al. 2009; Saijo et al. 2009; Wang et al. 2013a; Wang et al. 2013b). A home study from Japan found that an increased concentration of “Microbial Volatile Organic Compounds” (MVOC) in house was significantly associated with mucosal symptoms (Araki et al. 2010). Some studies also found an association between moldy odor and SBS symptoms in home environment (Engvall et al. 2001; Engvall et al. 2002; Kishi et al. 2009; Wang et al. 2013b). A number of studies found that condensation on windows panes and/or walls in residential homes was associated with SBS symptoms (Bornehag et al. 2003; Engvall et al. 2001; Kishi et al. 2009; Saijo et al. 2009; Wang et al. 2013a; Wang et al. 2013b). In the present study, we observed an association between dampness on bed/clothing and hoarse/dry throat symptom, which has not been found in other studies. Some other CCHH studies in Chongqing, China have found that frequent putting bed in sunshine could significantly reduce the risk of SBS symptoms (Wang et al. 2013a; Wang et al. 2013b), which is confirmed by the present study. Moreover, some studies also found an association between dampness index/score and SBS symptoms (Engvall et al. 2001; Engvall et al. 2002; Kishi et al. 2009; Wang et al. 2013b), and these investigations indicate that the increased dampness index could enhance the risk of SBS symptoms. In addition, some Swedish studies found that dampness or indoor molds in the dwellings were associated with increased incidence of SBS symptoms (Sahlberg et al. 2010; Sahlberg et al. 2012). Microbial contaminations including mold, yeasts, wood-rooting fungi, and bacteria due to dampness or moisture damage have been commonly reported in home environments (Nevalainen et al. 1991), which could affect human health by a variety of biological mechanisms, including infections, allergic or hypersensitivity reactions, and irritant

reactions. Some important allergens, such as house dust mites, cockroaches, cats or dogs commonly appeared in damp buildings have been suggested to be associated with allergic asthma, rhinitis eczema, and SBS symptoms in China (Li et al. 2009; Wang et al. 2013a; Zhang et al. 2011). Biological plausibility for associations between these bioaerosols and SBS symptoms have been provided by toxicological studies (Laumbach and Kipen 2005). However, the extent to which bioaerosol exposure may explain the nonspecific symptoms of the condition is still unclear and warrants further investigations.

Our finding that home redecoration was associated with weekly general SBS symptom (fatigue) is agreement with other studies. Some recent Chinese studies found associations between home renovations including new furniture and redecoration and SBS symptoms (Wang et al. 2013a; Wang et al. 2013b). Some Swedish studies suggested that emissions from newly painted indoor surfaces or renovations in dwellings were associated with SBS symptoms (Norbäck et al. 1996; Sahlberg et al. 2009; Sahlberg et al. 2012; Sahlberg et al. 2013). Previous experimental studies have found that complex mixtures of volatile organic compounds (VOCs) contributed to general symptoms including headaches, fatigue, and dizziness (Molhave 1992; Molhave et al. 1993). A number of studies about SBS in the home environment from Japan found that recent indoor painting (Takaoka and Norback 2011), chemicals emitted from renovations in newly built house (such as formaldehyde) (Takigawa et al. 2010), coating materials and volatile organic compounds (VOC) as well as semi-volatile organic compounds (SVOC) (Kanazawa et al. 2010; Nakayama and Morimoto 2009) were all associated with the risk of SBS symptoms. Moreover, another Japanese study found significant associations between home-related mucous symptoms and some specific microbial volatile organic compounds MVOCs including 1-octen-3-ol and 2-pentanol (Araki et al. 2010). A study in Taiwan found that VOC was associated with urinary 8-OHdG which was significantly higher in participants with SBS symptoms than in those without such complaints (Lu et al. 2007).

Our finding that window opening habits and the use of exhaust fan in bathroom were associated with less nose and dermal symptoms is agreement with some previous studies regarding building ventilation and SBS symptoms. Building ventilation can be measured either as CO₂ levels, personal outdoor air flow or air exchange rate (Norback 2009). In the present study, frequent opening windows and use of exhaust fan in bathroom could increase outdoor air flow and air exchange rate (Fabi et al. 2012), and thus dilute or remove CO₂ and other indoor air pollutants. A Swedish study has found that buildings with mechanical supply/exhaust ventilation, and consequently the highest airflow rate, had least dampness, which indicates that the good ventilation in dwellings could reduce the risk of SBS symptoms. A review study found that higher ventilation rates in offices, up to about 25 l/s per person (Sundell et al. 2011). This review emphasized the need remains for more studies of the relationship between ventilation rates and health, especially in diverse climates, in locations with polluted outdoor air and in buildings other than office. It has been suggested that window opening behavior has the largest effect on air change rates, causing increases ranging from a few tenths of an air change per hour to approximately two air changes per hour (Wallace et al. 2002). One study stated that opening of a single window increased the air change rate by an amount roughly proportional to the width of the opening, reaching increments as high as 1.3 h⁻¹, and multiple window openings increased the air change rate by amounts ranging from 0.10 to 2.8 h⁻¹ (Howard-Reed et al. 2002). Our finding highlights that frequent window opening and use of exhaust fan in bathroom could reduce SBS by increasing the ventilation

flow.

There are several limitations of this study that should be acknowledged. Firstly, epidemiological studies can be affected by selection bias. In this study, we included parents (one per child) from a cross-sectional study, with no prior information on parents' health status. The sample size was reasonably large, and the response rate was good (78%) and the 36 kindergarten were from all five major districts of Changsha. Thus, selection bias is fairly unlikely but the proportion of males in the study population was only 23% since the mothers answered the questionnaire more often than the fathers. However, since the study population consisted of young parents, expected to be mostly between 25 and 35 years old, results may not be representative for the entire adult population in Changsha. Moreover, information on socioeconomic status (SES) was limited and not used in this study since we had only self-reported data on the mother's occupation during pregnancy. Secondly, recall bias is another potential problem; subjects may overestimate or underestimate their personal symptoms and/or signs of indoor environment risk factors. Recall bias for moldy odor perceptions, and SBS symptoms should not be a big issue in this study, since the recall period was short (past three months). Information bias, in which subjects are aware that certain factors have previously been identified as risks, is another potential problem. However, the indoor factors studied in this paper (e.g. moldy odor), are not well known as creating indoor health problems among the Chinese population. The prevalence of weekly and sometimes perceptions of moldy odor perceptions were not high in our study (0.5% and 11.3%). Thirdly, we only had information on three air pollutants, PM₁₀, SO₂ and NO₂, to represent the ambient air pollution. In China, these pollutants have been paid great attention and have been routinely monitored and the levels have been published to the public (Kan et al. 2012). However, it is important to further investigate the roles of other pollutants, particularly PM_{2.5}, which can be a better proxy for traffic air pollution (Gehring et al. 2002; Hertz-Picciotto et al. 2007). Fourthly, exposure to air pollution was modeled by using an inverse distance weighted (IDW) method based on the data from ambient air quality monitoring stations. This modeling method may lead to bias of exposure because the number of monitoring stations was few and the sources of the air pollution and the land use conditions were ignored. Finally, as the first step of the nationwide project (CCHH), our study only included one city. Additional research in other cities is needed to confirm the persistence and generalizability of the results, given that the concentration levels of the air pollutants in our study were comparable to those recorded in a number of cities in China (Chan and Yao 2008; Kan et al. 2012). Finally, the cross-sectional study design limits the possibility to draw conclusions on causality.

5. Conclusions

In conclusion, adults' SBS symptoms can be associated with a history of asthma and allergic rhinitis (atopy). Indoor factors, especially mold/dampness, could play an important role for SBS symptoms in Chinese adult residents in this area of China. Furthermore, indoor redecoration could increase fatigue, and high ventilation flow rate could reduce the risk of nose and dermal symptoms. Our results suggest that it is beneficial with respect to SBS symptoms to reduce household mold/dampness, control air pollution emissions from home renovations, and encourage improving building ventilation through frequent opening windows

use of an exhaust fan in bathroom.

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• **Table 1**

Number and prevalence of sick building symptoms stratified by demographic information on participating parents (n = 3,485).

		Total n=3,485 (%)	Gender			History of atopy			Current smoking		
SBS symptoms	Frequency		Male (n=808) (%)	Female (n=2,677) (%)	P	No (n=3,268) (%)	Yes (n=217) (%)	p	No (n=3,010) (%)	Yes (n=440) (%)	p
General symptoms											
Fatigue	Never/sometimes	2,862 (85.4)	86.0	85.2	0.589	86.0	75.9	<0.001	85.4	85.4	0.982
	Weekly	489 (14.6)	14.0	14.8		14.0	24.1		14.6	14.6	
Headache	Never/sometimes	3,047 (95.8)	97.8	95.3	0.003	96.1	92.0	0.005	95.7	97.1	0.175
	Weekly	132 (4.2)	2.2	4.7		3.9	8.0		4.3	2.9	
Mucosal symptoms											
Itching, burning or irritation of eyes	Never/sometimes	3,045 (96.8)	98.2	96.3	0.014	97.4	87.1	<0.001	96.5	98.4	0.048
	Weekly	102 (3.2)	1.8	3.7		2.6	12.9		3.5	1.6	
Irritating, stuffy or runny nose	Never/sometimes	3,035 (96.6)	97.8	96.3	0.054	98.1	76.0	<0.001	96.5	97.7	0.248
	Weekly	106 (3.4)	2.2	3.7		1.9	24.0		3.5	2.3	
Hoarse, dry throat	Never/sometimes	3,024 (95.2)	95.9	94.9	0.308	95.5	90.4	0.001	95.2	94.6	0.613
	Weekly	154 (4.8)	4.1	5.1		4.5	9.6		4.8	5.4	
Dermal symptoms											
Any dermal symptom #	Never/sometimes	3,042 (95.7)	96.6	95.4	0.157	96.1	90.1	<0.001	95.6	95.8	0.858
	Weekly	137 (4.3)	3.4	4.6		3.9	9.9		4.4	4.2	

1) N and % (within the parentheses) of responses on reported diseases and symptoms in different stratified group were calculated when the missing data was excluded.
2) P-value was calculated by chi-squared test on prevalence of diseases and symptoms between different stratified groups.

Table 2

Descriptive statistics of **calculated individual** air pollution exposure levels and meteorological parameters during last three months (n = 3,485).

	Mean $\pm$ SD	Minimum	25 th percentile	50 th percentile	75 th percentile	Maximum
Air pollution exposure						
PM ₁₀	80 $\pm$ 13	53	73	79	85	121
SO ₂	31 $\pm$ 5	22	28	30	33	51
NO ₂	40 $\pm$ 5	31	36	40	42	63
Meteorological parameters exposure						
T	25.2 $\pm$ 2.9	13.9	22.6	26.3	27.7	28.0
RH	75.6 $\pm$ 1.3	74.1	74.5	75.4	76.9	78.3
WS	2.4 $\pm$ 1.5	0.83	1.4	1.7	2.2	6.4

Abbreviations: SD, standard deviation; PM₁₀ ($\mu\text{g}/\text{m}^3$), particulate matter $\leq 10 \mu\text{m}$ in aerodynamic diameter, SO₂ ($\mu\text{g}/\text{m}^3$), sulfur dioxide; NO₂ ($\mu\text{g}/\text{m}^3$), nitrogen dioxide; T ($^{\circ}\text{C}$), temperature; RH (%), relative humidity; WS (m/s), wind speed.

Table 3

Descriptive statistics of indoor factors (n = 3,485).

Indoor factors	Variable	Number	Percentage (%)
Building characteristics			
Building age (year)	< 10	1,867	55.3
	≥ 10	1,508	44.7
House size (m ²)	< 75	2,384	69.4
	≥ 75	1,051	30.6
Mold/dampness			
Mold/damp stains on floor or ceiling	No	2,870	87.6
	Yes	408	12.4
Moldy odour	No	2,887	88.2
	Yes	386	11.8
Dampness on bed/clothing	No	1,935	56.3
	Yes	1,504	43.7
Window pane condensation in winter	No	1,110	48.5
	Yes	1,181	51.5
Water damage	No	2,914	89.5
	Yes	343	10.5
Putting bedding in sunshine	Never/sometimes	1,368	39.7
	Frequently	2,074	60.3
Dampness score †			
0	No variable	1167	33.6
1	1 variable	1267	36.5
2	2 variables	664	19.1
>2	>2 variables	377	10.8
Indoor air pollution			
New furniture (after the child > 1 year)	No	1,870	61.4
	Yes	1,175	38.6
Redecoration (after the child > 1 year)	No	2,382	80.8
	Yes	567	19.2
ETS at home #	No	1,146	33.2
	Yes	2,304	66.8
Ventilation			
Window opening habits	Never/sometimes	1,250	36.5
	Frequently	2,173	63.5
Mechanical ventilation in kitchen	No/only fan	1,140	33.4
	Smoke exhaust ventilator	2,277	66.6
Exhaust fan in bathroom	No	685	20.2
	Yes	2,711	79.8

Any people among the child's mother, father, grandmother, grandfather, brothers or sisters of the child, and others living at home smokes.

† Dampness score was defined by the cumulated number of presence of the mold/dampness variables among mold/damp on floor/ceiling, moldy odour, dampness on bed/clothing, window pane condensation in winter, and water damage.

Table 4

Correlation between **calculated individual levels of** air pollutants and meteorological parameters during last three months (**n=3685**).

	PM ₁₀	SO ₂	NO ₂	T	RH	WS
PM ₁₀	1	0.597 **	0.824 **	-0.601 **	0.546 **	-0.103 **
SO ₂		1	0.470 **	-0.319 **	0.192 **	-0.164 **
NO ₂			1	-0.693 **	0.550 **	-0.035 *
T				1	-0.921 **	0.209 **
RH					1	-0.220 **
WS						1

*, Correlation is significant at the 0.05 level (2-tailed), **, Correlation is significant at the 0.01 level (2-tailed).

Table 5

Associations of exposure to outdoor air pollution and meteorological parameters during last three months with SBS symptoms by 2-level hierarchic (child, kindergarten) multiple logistic regression models (n = 3,485).

		General symptoms		Mucosal symptoms			Dermal symptoms #
		Fatigue	Headache	Itching, burning or irritation of eyes	Irritating, stuffy or runny nose	Hoarse, dry throat	Any weekly dermal symptom
IQR		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Three months exposure to air pollution †							
PM ₁₀	12 (µg/m ³)	0.92 (0.80, 1.06)	0.92 (0.75, 1.13)	0.94 (0.73, 1.19)	1.18 (0.92, 1.51)	1.00 (0.82, 1.21)	0.98 (0.79, 1.21)
SO ₂	5 (µg/m ³)	0.97 (0.86, 1.11)	0.84 (0.69, 1.02)	0.91 (0.71, 1.17)	1.32 (1.01, 1.72)*	1.13 (0.93, 1.38)	1.07 (0.87, 1.32)
NO ₂	6 (µg/m ³)	1.05 (0.87, 1.27)	0.90 (0.68, 1.19)	0.99 (0.72, 1.38)	1.21 (0.87, 1.69)	1.13 (0.87, 1.47)	1.12 (0.84, 1.51)
Three months exposure to meteorological parameters ‡							
T	5 (°C)	1.20 (0.96, 1.53)	1.04 (0.76, 1.42)	1.51 (1.02, 2.24)*	0.96 (0.67, 1.37)	1.15 (0.86, 1.54)	0.99 (0.72, 1.35)
RH	2 (%)	0.82 (0.68, 0.99)*	1.06 (0.80, 1.40)	0.72 (0.52, 1.01)	1.02 (0.74, 1.41)	0.81 (0.62, 1.06)	0.95 (0.71, 1.26)
WS	0.83 (m/s)	1.02 (0.97, 1.08)	0.99 (0.90, 1.09)	1.01 (0.90, 1.13)	0.99 (0.88, 1.12)	0.94 (0.85, 1.03)	1.07 (0.98, 1.17)

† Adjusted for gender, current smoking, history of atopy, T, and WS during last three months.

‡ Adjusted for gender, current smoking, and history of atopy.

Dermal symptoms is defined as any weekly dermal symptom among dry/flushed facial skin, scaling/itching scalp or ears, and hands dry/itching/red skin.

* p<0.05.

OR's are calculated per IQR increase of calculated individual exposure

Table 6

Pearson correlations between outdoor and indoor factors (n = 3,485).

	SO ₂	T	Building age	House size	Window opening	Mold/dampness	Mold odor	Dampness on clothing/bed	Put bedding in sunshine	Window pane condensation	Water damage	New furniture	Redecoration	ETS
SO ₂	1	-0.319 **	0.175 **	0.111 **	-0.053 **	-0.012	-0.008	-0.028	-0.002	-0.076 **	-0.005	-0.041 *	-0.031	0.017
T		1	-0.050 **	-0.096 **	0.072 **	0.011	0.019	0.055 **	0.024	0.051 *	-0.002	-0.013	-0.039 *	-0.062 **
Building age			1	0.420 **	0.009	0.073 **	0.103 **	0.030	0.022	-0.096 **	0.013	-0.170 **	-0.182 **	0.078 **
House size				1	-0.016	0.069 **	0.103 **	0.039 *	-0.007	-0.098 **	0.028	-0.128 **	-0.113 **	0.045 **
Window opening					1	-0.016	-0.018	-0.002	0.080 **	-0.038	-0.001	0.024	0.024	-0.038 *
Mold/dampness						1	0.241 **	0.208 **	-0.028	0.103 **	0.134 **	-0.070 **	-0.053 **	0.007
Mold odor							1	0.231 **	-0.065 **	0.091 **	0.123 **	-0.027	-0.028	0.033
Dampness on bed/clothing								1	-0.035 *	0.203 **	0.086 **	-0.016	-0.042 *	0.002
Put bedding in sunshine									1	-0.035	-0.084 **	-0.057 **	-0.023	-0.015
Window pane condensation										1	0.101 **	0.060 **	0.017	-0.025
Water damage											1	0.025	-0.013	0.024
New furniture												1	0.499 **	-0.026
Redecoration													1	-0.028
ETS														1

*. Correlation is significant at the 0.05 level (2-tailed), **. Correlation is significant at the 0.01 level (2-tailed).

Table 7

Associations between exposure to indoor factors and SBS symptoms (n = 3,485).

Indoor factors	Variable	General symptoms		Mucosal symptoms			Dermal symptoms #
		Fatigue OR † (95% CI)	Headache OR † (95% CI)	Itching, burning or irritation of eyes OR † (95% CI)	Irritating, stuffy or runny nose OR † (95% CI)	Hoarse, dry throat OR † (95% CI)	Any weekly dermal symptom OR † (95% CI)
Building characteristics							
Building age (year)	≥ 10 vs. < 10	0.80 (0.66, 0.98)*	1.07 (0.74, 1.54)	1.02 (0.67, 1.55)	0.96 (0.63, 1.48)	0.73 (0.52, 1.03)	0.82 (0.57, 1.17)
House size (m²)	< 75 vs. ≥ 75	0.79 (0.63, 0.98)*	0.91 (0.61, 1.36)	0.76 (0.46, 1.24)	0.86 (0.53, 1.39)	0.92 (0.64, 1.33)	1.03 (0.71, 1.51)
Mold/dampness							
Mold/damp on floor/ceiling	Yes vs. no	1.64 (1.26, 2.14)***	1.89 (1.21, 2.94)**	1.64 (0.98, 2.75)	1.05 (0.57, 1.94)	1.65 (1.06, 2.55)*	1.78 (1.14, 2.78)*
Moldy odour	Yes vs. no	1.84 (1.41, 2.42)***	1.77 (1.10, 2.86)*	1.92 (1.14, 3.24)*	1.64 (0.90, 2.99)	1.91 (1.23, 2.95)**	2.08 (1.33, 3.25)(***)
Dampness on bed/clothing	Yes vs. no	1.47 (1.21, 1.79)***	1.43 (1.00, 2.04)*	1.65 (1.09, 2.50)*	0.94 (0.62, 1.43)	1.61 (1.16, 2.24)**	1.19 (0.84, 1.69)
Window pane condensation in winter	Yes vs. no	1.82 (1.41, 2.33)***	1.47 (0.95, 2.26)	1.65 (0.98, 2.77)	1.33 (0.79, 2.24)	1.72 (1.15, 2.59)**	1.39 (0.90, 2.14)
Water damage	Yes vs. no	1.12 (0.82, 1.53)	1.26 (0.74, 2.13)	2.14 (1.26, 3.62)**	1.36 (0.74, 2.52)	0.73 (0.40, 1.33)	1.41 (0.85, 2.34)
Putting bedding under sunshine	Yes vs. no	0.74 (0.61, 0.90)**	0.88 (0.62, 1.25)	0.81 (0.54, 1.22)	0.53 (0.35, 0.81)**	0.73 (0.53, 1.02)	0.74 (0.52, 1.05)
Dampness score							
0	No variable	1.00	1.00	1.00	1.00	1.00	1.00
1	1 variable	1.42 (1.10, 1.82)**	1.41 (0.87, 2.28)	1.61 (0.90, 2.89)	1.77 (1.02, 3.08)*	1.58 (1.00, 2.50)*	1.10 (0.70, 1.73)
2	2 variables	1.60 (1.20, 2.13)(***)	2.12 (1.29, 3.50)**	2.29 (1.25, 4.21)**	1.84 (1.01, 3.37)*	2.72 (1.70, 4.35)***	1.42 (0.87, 2.33)
>2	>2 variables	2.65 (1.94, 3.60)***	2.13 (1.20, 3.81)(**)	3.20 (1.67, 6.15)***	1.30 (0.60, 2.83)	2.32 (1.32, 4.07)**	2.23 (1.32, 3.77)**
Indoor air pollution							
New furniture	Yes vs. no	1.40 (1.14, 1.72)**	0.82 (0.55, 1.21)	1.30 (0.85, 1.99)	0.77 (0.48, 1.24)	1.08 (0.76, 1.54)	1.32 (0.91, 1.91)
Redecoration	Yes vs. no	1.45 (1.13, 1.86)**	1.02 (0.63, 1.64)	1.01 (0.59, 1.75)	0.85 (0.47, 1.53)	0.95 (0.61, 1.48)	1.32 (0.86, 2.03)
ETS at home	Yes vs. no	0.93 (0.75, 1.16)	1.34 (0.89, 2.02)	1.10 (0.70, 1.71)	1.97 (1.19, 3.26)**	1.75 (1.16, 2.62)**	1.19 (0.80, 1.77)
Ventilation							
Window opening habits	F vs. N/S	0.80 (0.66, 0.98)*	0.98 (0.68, 1.42)	0.65 (0.44, 0.98)*	0.55 (0.36, 0.83)**	0.85 (0.61, 1.19)	1.04 (0.72, 1.48)
Mechanical ventilation in kitchen	Yes vs. no	1.20 (0.97, 1.49)	1.00 (0.69, 1.46)	0.87 (0.57, 1.34)	1.24 (0.79, 1.95)	1.10 (0.78, 1.58)	0.94 (0.65, 1.36)
Exhaust fan in bathroom	Yes vs. no	0.87 (0.69, 1.11)	0.77 (0.51, 1.18)	0.78 (0.48, 1.27)	0.94 (0.55, 1.62)	1.00 (0.66, 1.52)	0.65 (0.43, 0.97)*

† Adjusted for gender, current smoking, history of atopy, outdoor T, WS, and SO₂ exposure during last three months by **multiple logistic regression models**.

Dermal symptoms were defined by any weekly dermal symptom among dry/flushed facial skin, scaling/itching scalp or ears, and hands dry/itching/red skin.

* p<0.05, ** p<0.01, (**) p=0.01, *** p<0.001, (***) p=0.001.

Table 8

Associations of exposure to outdoor air pollution and meteorological parameters during last three months with SBS symptoms using **stepwise multiple logistic regression models** (n = 3,485).

	OR (95% CI)	Wald	p
Fatigue			
Window pane condensation in winter	1.73 (1.30, 2.31)	14.09	<0.001
Mold/dampness on floor/ceiling	1.60 (1.11, 2.30)	6.28	0.012
Redecoration	1.49 (1.07, 2.06)	5.68	0.017
Moldy odour	1.59 (1.07, 2.37)	5.33	0.021
WS (per 0.83 m/s)	1.07 (1.00, 1.14)	3.34	0.068
Dampness on bed/clothing	1.30 (0.98, 1.73)	3.24	0.072
History of atopy	1.56 (0.96, 2.54)	3.24	0.072
Gender	0.88 (0.60, 1.31)	0.39	0.533
Current smoking	0.96 (0.58, 1.59)	0.03	0.858
Headache			
History of atopy	2.43 (1.30, 4.53)	7.73	0.005
Mold/dampness on floor/ceiling	1.80 (1.07, 3.04)	4.84	0.028
Gender	2.01 (0.93, 4.38)	3.11	0.078
Window pane condensation in winter	1.47 (0.95, 2.28)	2.93	0.087
Current smoking	1.33 (0.52, 3.42)	0.36	0.551
Itching, burning or irritation of eyes			
History of atopy	5.50 (3.43, 8.84)	49.77	<0.001
Window opening habits	0.69 (0.46, 1.03)	3.31	0.069
Gender	1.75 (0.85, 3.59)	2.30	0.130
Current smoking	0.69 (0.25, 1.91)	0.51	0.477
Irritating, stuffy or runny nose			
History of atopy	16.56 (10.86, 25.26)	170.10	<0.001
Window opening habits	0.54 (0.36, 0.82)	8.26	0.004
Gender	1.71 (0.83, 3.52)	2.09	0.148
Current smoking	1.03 (0.40, 2.61)	0.00	0.957
Hoarse, dry throat			
Dampness on bed/clothing	1.62 (1.09, 2.40)	5.63	0.018
History of atopy	2.01 (1.09, 3.73)	4.95	0.026
Window pane condensation in winter	1.53 (1.01, 2.31)	4.00	0.045
Gender	1.68 (0.85, 3.32)	2.26	0.133
Current smoking	1.68 (0.75, 3.74)	1.59	0.208
PM ₁₀ (per 12 µg/m ³)	0.91 (0.75, 1.09)	1.07	0.301
Dermal symptoms #			
History of atopy	2.58 (1.51, 4.42)	11.87	0.001
Mold odor	1.91 (1.21, 3.02)	7.59	0.006
Exhaust fan in bathroom	0.66 (0.44, 0.99)	4.01	0.045
Gender	1.76 (0.93, 3.35)	2.99	0.084
Current smoking	1.58 (0.74, 3.37)	1.41	0.235

The models include variables retained in a stepwise logistic regression model (forward regression Wald statistics, p<0.10). These variables were entered in a multiple logistic regression model (enter) adjusting for gender, current smoking, and history of atopy.

Dermal symptoms is defined as any weekly dermal symptom among dry/flushed facial skin, scaling/itching scalp or ears, and hands dry/itching/red skin.