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A cross-sectional study into the correlation of common household risk factors and allergic rhinitis in Taiwan's tropical environment

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ABSTRACT

Objective: To discuss the effect of lesser-known potential risk factors, such as bedroom showers, on the prevalence of allergic rhinitis.

Method: A cross-sectional, population-based study was performed using both survey and fungal culturing in southern Taiwan. There were 998 participants enrolled in the survey, and 513 sets of fungal culture obtained. With score for allergic rhinitis (SFAR) more than 7, the patient was defined to have allergic rhinitis. Risks of allergic rhinitis were calculated as odds ratios for various predicted risk factors by logistic regression. Correlation between predicted risk factors and fungal level were examined with linear regression.

Results: The adjusted odds ratio of frequently using bedroom shower to having allergic rhinitis was 1.572 (95% confidence interval: 1.090–2.265), and 0.962 for people with older age to have AR (95% confidence interval: 0.949–0.976). As to the 24-hour fungal level, the standardized coefficient was 0.254 for frequent use of bedroom shower, and 0.106 for window open hours.

Conclusions: Use of bedroom shower is a potential risk factor for allergic rhinitis development.

1. Introduction

Over the past few decades, atopic disorders have shown a gradual rise in prevalence among the global population. Studies across numerous nations have suggested an increasing trend of atopic disorders, such as asthma and allergic rhinitis (AR). Furthermore, allergic rhinitis has now been identified as one of the most common disease among several nations across the globe [1,2]. The ARIA update in 2008 have estimated about 400 million people suffered from AR globally [1]. In the United States, allergic rhinitis has been recognized as the most common atopic disorder in the country, with the number of individuals with AR-associated symptoms reaching up to at least 35.9 million persons [2]. In Taiwan, a national study from 2000 to 2007 has identified the prevalence of AR to be about 26.3% of the total population [3].

Studies into the possible risk factors of allergic rhinitis have identified dampness and mold contamination of indoor environment as one of the primary risk factors for AR development [4–9]. Correlations between AR and ‘signs of dampness’, including the presence of mold spots, moldy odor, and water damage, were observed in the abovementioned studies. Further investigation into the relationship of indoor fungal level and home dampness revealed positive correlation between the two

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factors [10–12]. Examinations, under lab setting, of the effect of humidity on fungal growth provided further evidence that humidity served as an important factor for propagation of mold species [13,14]. Other additional investigation carried out in countries and locations with higher relative humidity have also shown increased ambient fungal level compared to other locations with lower humidity [7–15]. Taiwan, being a tropical island, has on average relatively high humidity all year round. Heavy seasonal rain, humid seasonal monsoon, and warm ocean current have all contributed to Taiwan's high humidity (about 70–85% average relative humidity all year) [16,17]. Taiwan's high average humidity and temperature provided an ideal condition for the growth of fungus.

The majority of current studies into the relationship of AR and indoor dampness have usually characterized 'dampness' under several home environmental characteristic. The most common characteristics referred to the presence of 'mold spots', 'moldy odor', and 'water damage' as defining traits of 'dampness' [5,7,9,18]. However, very little was known about other less-concerned source of indoor dampness. One such possible source was the presence of shower in the bedroom. Bedroom was where the majority of our time were spent (with a large portion of time spent sleeping in the bedroom). The en suite type bedroom usually featured shower and bathroom within the bedroom for easier access and better privacy for bedroom occupants. The frequent use of shower in bedroom could produce high level of humidity in the bedroom, making it a potential source of indoor dampness. The accumulation of humidity from shower could have provided ideal growth condition for mold species. As a result, mold contamination of the bedroom could occur. This was especially applicable in Taiwanese household due to Taiwan's already-high average humidity.

In addition to home dampness and fungal growth, previous studies have also identified poor home ventilation as possible risk factor for AR [9,19–23]. In this regard, several studies have indicated that poor air flow rate between indoor and outdoor air could result in the trapping of indoor allergens, including mold spores, house dust mites (HDM), and air moistures [22,23]. On the contrary, improved ventilation promoted air exchange between indoor and outdoor air, allowing the dispersion of indoor allergens outside.

All in all, this study aimed to investigate the relationship between prevalence of allergic rhinitis with several little-understood potential indoor risk factors. The investigation of vaguely-understood potential risk factors could offer new insights into enacting better preventive measure against AR risk factors, allowing for more effective home improvement plan and treatment of AR through environmental improvement. The identification of new AR risk factors could also provide additional information on the ever-expanding data on indoor risk factors, and allowed the establishment of better architectural and home-design guidelines in order to minimize the exposure of allergens to home occupants.

2. Materials and methods

2.1. Study design and sample population

To investigate the correlation of AR with potential risk factors, a cross-sectional, population-based study was performed in Kaohsiung area of Taiwan. To be included in the study, participants must be of age 20 or above, and mustn't have handicaps that prevent understanding of the survey in accordance to IRB regulations. A total of 1009 participants were randomly selected for the study, but 11 were excluded due to being under the required age for inclusion. Participants included were mostly local Taiwanese, with few foreigners of American origin mixed in. The selection process consisted of a team of researchers, stationed at Anshing Clinic, Kaohsiung, who recruited any visiting patient or accompanying relative willing to participate in the study. The study was divided into 2 parts: 1) Survey investigation and 2) Mold sampling and culture. A total of 998 participants were included in the survey investigation. Out of these 998 participants, 513 also volunteered for indoor air sampling and mold cultures.

2.2. Survey investigation

The survey investigation was divided into two categories: home environment and AR status assessment. For assessment of home environment, the participants were asked about the presence of Japanese style wooden floor or wall within their bedrooms. The participants were also inquired about the presence of bathroom in the bedroom, and the frequency of the bathroom use. In addition, the participants were inquired about their habit of opening window periodically, and the number of hours the window is usually opened. Common 'signs' of indoor dampness, included mold spots, moldy odor, and water leak, were also assessed. Finally, several minor parameters were also assessed, which included participants' daily cleaning habit, recent redecoration (within the past 3 months), periodic bedding change, and age of current home. Participants and other home occupants' smoking habit were also assessed.

For the participant's AR status, the score for allergic rhinitis (SFAR), developed and proposed in Annesi-Maesano *et al.*, was used for this assessment. SFAR covered a wide range of common clinical diagnostic parameters for allergic rhinitis [24]. SFAR assessed for the participants' AR symptoms (both nasal and ocular), duration of symptoms, potential triggers, professional diagnosis, IgE/SPT test results, and family history of atopic disorders. SFAR contained a total of 16 possible points, with the cutoff point at 7 points. Individuals with SFAR higher or equal to 7 were therefore considered to have AR, and vice versa [24]. In this survey investigation, SFAR was translated into Chinese and incorporated into the survey questionnaire. English version of the survey was also available for foreign participants.

2.3. Air sampling and mold culture

In order to investigate the role of fungal growth in relation to other risk factors proposed in this study, air sample and mold culture were done to assess the fungal level of the participants' indoor air. Air sampling was done through the settled dust method. A total of 513 participants from the survey population volunteered to be given 3 Sabouraud Dextrose Agar (SDA) plates per person. The participants were instructed to place the 3 SDA plates on floor level in the center of their bedrooms with about 2 m apart from each plate. The participants were then further instructed to open the cover of the 3 SDA plates, and exposed the plates to ambient air for 3 h before re-covering the plates and returning the plates for incubation.

The recovered SDA plates were incubated for 48 h at 28–30 °C. The plates were taken out after 48 h, and the colony forming units (CFUs) were counted for all 3 plates. The average of the CFUs count from the 3 plates was calculated. Plates that have suffered physical damage, dehydration, infestation by other animals, or came into physical contact with foreign objects (*i.e.* human touch, *etc.*) were excluded as it either no longer reflect the fungal level present in the ambient air or were too damaged to be identifiable. A total of 6 participants were excluded due to one of the above-mentioned reasons, and a total of 507 participants were included in the final analysis.

2.4. Statistical analysis

Univariate logistic regression was used to examine the correlation between SFAR results and various potential risk factors proposed (*i.e.* bedroom shower, wooden furniture and decorations, ventilation habits, *etc.*). Univariate linear regression was performed to investigate the correlation between CFUs and the proposed risk factors. Multiple linear regression and logistic regression were performed, in addition, under similar fashion to correct for any potential confounding variables. All statistical calculation was done using Statistical Product and Service Solution (SPSS Statistic) package from IBM Corporation, NY, USA.

2.5. Ethic statement

This study has been approved by the Institutional Review Board of Kaohsiung Veterans General Hospital, Taiwan. All participants involved have been provided with and signed an informed consent form.

3. Results

The demographic summary of the collected data is displayed in Table 1. Out of the 998 participants collected, 38% of the participants were male and 62% were female. The mean age of the sample participants were around 42.02 years old with a standard deviation of 14.647. In addition, 30.2% of the participants have been considered by SFAR to have allergic rhinitis. The mean SFAR score was 4.88 with a standard deviation of 4.156.

To analyze the correlation between multiple indoor risk factors and SFAR score, univariate logistic regression was performed. The analysis results were presented in Table 2 as odds ratios, with 95% confidence interval and significance level. As shown in Table 2, age seemed to have extremely significant negative correlation with SFAR score (*OR* = 0.962). In addition, the presence of pet has shown significant positive correlation with SFAR score (*OR* = 1.384). In terms of bathroom and toilets in bedroom, the presence of toilet and bathroom in the bedroom by itself had no significant correlation. However, the presence of a bathroom in combination with frequent use of bathroom has shown significant positive correlation to SFAR score, holding an odds ratio of 1.410. Frequent opening of window has shown negative correlation (*OR* = 0.681). The opening hours of windows also indicated a negative correlation (*OR* = 0.892). Age of house has shown to be negatively correlated with SFAR score (*OR* = 0.979).

In order to correct the effects of confounding variables, the data were adjusted for confounders by using multiple logistic regression. The summary of multiple logistic regression results was shown in Table 3. The independent predictors of AR were age (*OR* = 0.962; 95% *CI*: 0.949–0.976) and frequent use of bedroom shower (*OR* = 1.572; 95% *CI*: 1.090–2.625).

Univariate linear regression analysis with CFUs from mold cultures was performed, and the data were showed in Table 4. To eliminate the confounding effect, the regression analysis was adjusted using multiple linear regression, and the summary of

Table 1

Demographic data for gender, age, household environment, ventilation habit, smoking habit, and average CFUs.

Variable	Numbers
Gender (male)	379 (38.0%)
Age (years)	42.020 ± 14.647
Diabetes mellitus (+)	51 (5.1%)
Hypertension (+)	98 (9.8%)
Mold spots (+)	280 (28.1%)
Water leakage (+)	92 (9.2%)
Moldy odor (+)	110 (11.0%)
Pet (+)	254 (25.5%)
Plant (+)	174 (17.4%)
Wood floor (+)	252 (25.3%)
Wood wall (+)	96 (9.6%)
Toilet in bedroom (+)	471 (47.2%)
Bathroom in bedroom (+)	457 (45.8%)
Windows in bathroom (+)	392 (39.3%)
Frequent usage of showers in bedroom bathroom (+)	392 (39.3%)
Number of windows	1.320 ± 0.767
Frequent opening of windows (+)	819 (82.1%)
Window-open time (hour)	3.520 ± 1.543
Age of house (year)	18.420 ± 9.958
Daily cleaning (+)	364 (36.5%)
Redecoration (+)	19 (1.9%)
Bedding takeout (+)	391 (39.2%)
Smoke (+)	384 (38.5%)
Score for allergic rhinitis	4.880 ± 4.156
Allergic rhinitis (+)	301 (30.2%)
48 h colony numbers	54.61 ± 46.18

Total numbers = 998. Data are expressed as mean ± standard deviation.

Table 2

Different variables affecting the allergic rhinitis (SFAR $\geq$ 7) were analyzed with univariate logistic regression.

Variable	*OR*	95% *CI*	*P* value
Gender (male)	0.844	0.637–1.118	0.238
Age (years)	0.962	0.952–0.972	<0.001**
Diabetes mellitus (+)	0.963	0.519–1.787	0.905
Hypertension (+)	0.527	0.313–0.887	0.016*
Mold spots (+)	1.037	0.768–1.400	0.812
Water leakage (+)	1.477	0.947–2.304	0.085
Moldy odor (+)	1.433	0.948–2.165	0.088
Pet (+)	1.384	1.022–1.872	0.035*
Plant (+)	1.156	0.815–1.641	0.417
Wood floor (+)	1.190	0.876–1.616	0.267
Wood wall (+)	0.847	0.528–1.358	0.490
Toilet in bedroom (+)	0.992	0.756–1.301	0.951
Bathroom in bedroom (+)	0.984	0.749–1.292	0.907
Windows in bathroom (+)	1.224	0.927–1.617	0.154
Frequent usage of showers in bedroom bathroom (+)	1.410	1.039–1.912	0.027*
Number of windows	1.083	0.909–1.291	0.372
Frequent opening of windows (+)	0.681	0.484–0.959	0.028*
Window-open time	0.892	0.818–0.973	0.010*
Age of house	0.979	0.964–0.994	0.005**
Daily cleaning (+)	0.904	0.682–1.200	0.486
Redecoration (+)	0.827	0.295–2.318	0.718
Bedding takeout (+)	0.867	0.655–1.147	0.316
Smoke (+)	1.285	0.976–1.693	0.074

*P < 0.05 compared with control group; **P < 0.01 compared with control group.

Table 3

Independent risk factors of allergic rhinitis, evaluated by multiple logistic regression analysis.

Variable	*OR*	95% *CI*	*P* value
Age (years)	0.962	0.949–0.976	<0.001**
Hypertension (+)	0.644	0.318–1.305	0.222
Mold spots (+)	0.874	0.569–1.343	0.538
Water leakage (+)	1.084	0.582–2.019	0.798
Moldy odor (+)	1.066	0.596–1.905	0.829
Pet (+)	1.263	0.842–1.896	0.259
Wood floor (+)	1.089	0.728–1.627	0.679
Wood wall (+)	0.887	0.455–1.731	0.726
Frequent usage of showers in bedroom bathroom (+)	1.572	1.090–2.265	0.015*
Frequent opening of windows (+)	0.712	0.388–1.307	0.273
Window-open time	0.956	0.820–1.115	0.568
Age of house	1.001	0.982–1.021	0.882

Odds ratio were adjusted for age, hypertension, mold spots, water leakage, moldy odor, pet, wood floor, wood wall, frequent usage of showers in bedroom bathroom, frequent opening of windows, window-open time, age of house in full model.
*P < 0.05 compared with control group; **P < 0.01 compared with control group.

results could be found in Table 5. The use of shower in bedroom once again has shown significant correlation with CFUs count. Both wooden floor and wooden wall have shown no significant correlation again with CFUs. The opening hours for windows has also shown significant positive correlation again with CFUs. Common 'signs' of dampness, such as mold spots, water leak, and moldy odor, did not showed any significant correlation. In addition, status of allergic rhinitis has shown to be positively correlated with CFUs count. In summary, the only variables that have shown significant correlation with CFUs were: 'frequent use of showers in bedroom', 'opening hours of window', and 'allergic rhinitis' status, after adjustment with multiple linear regression.

Table 4

The relationship between different variable and the 48-hour colony numbers was analyzed with univariate linear regression.

Variable	Standardized coefficient (s)	*P* value
Gender (female)	0.001	0.968
Age (years)	0.008	0.808
Diabetes mellitus (+)	0.069	0.030*
Hypertension (+)	−0.003	0.924
Mold spots (+)	−0.011	0.727
Water leakage (+)	−0.027	0.391
Moldy odor (+)	0.016	0.624
Pet (+)	−0.005	0.868
Plant (+)	−0.02	0.529
Wood floor (+)	−0.011	0.727
Wood wall (+)	−0.011	0.737
Toilet in bedroom (+)	0.008	0.808
Bathroom in bedroom (+)	0.007	0.83
Windows in bathroom (+)	−0.031	0.341
Frequent usage of showers in bedroom bathroom (+)	0.098	0.005**
Number of windows	0.009	0.783
Frequent opening of windows (+)	0.037	0.246
Window-open time	0.087	0.006**
Age of house	0.016	0.646
Daily cleaning (+)	0.016	0.608
Redecoration (+)	−0.051	0.113
Bedding takeout (+)	0.034	0.293
Smoke (+)	−0.027	0.402
Allergic rhinitis (+)	0.081	0.011*

*P < 0.05 compared with control group; **P < 0.01 compared with control group.

Table 5

Independent risk factors of 48-hour colony numbers, evaluated by multiple linear regression analysis.

Variable	Standardized coefficient (in)	*P* value
Diabetes mellitus (+)	0.060	0.092
Mold spots (+)	−0.005	0.884
Water leakage (+)	−0.052	0.158
Moldy odor (+)	0.022	0.548
Pet (+)	0.009	0.796
Plant (+)	−0.026	0.468
Wood floor (+)	−0.028	0.427
Wood wall (+)	−0.009	0.790
Toilet in bedroom (+)	−0.057	0.603
Bathroom in bedroom (+)	−0.136	0.238
Frequent usage of showers in bedroom bathroom (+)	0.254	<0.001**
Window-open time	0.106	0.003**

Standardized coefficient were adjusted for diabetes mellitus, mold spots, water leakage, moldy odor, pet, plant, wood floor, wood wall, toilet in bedroom, bathroom in bedroom, frequent usage of showers in bedroom bathroom, window-open time in full model.
*P < 0.05 compared with control group; **P < 0.01 compared with control group.

4. Discussion

4.1. Shower in bedroom as a potential source of indoor dampness

After examination of the relationship of potential risk factors with survey and mold cultures results, the use of shower in bedroom has been identified to have significantly positive correlation with the presence of allergic rhinitis and increasing CFUs. Bedroom shower as a risk factor was a poorly understood concept, but not an implausible one. While the use of shower itself was not well-understood, the presence of dampness and its effect on indoor environment and health of home occupants has been shown by numerous studies to be significant. Previous studies into the effect of indoor dampness and home occupants' atopic status have observed positive correlation between indoor dampness and an increasing risk of AR [5,7,25–27]. Homes that have been identified to contain the usual 'signs' of dampness, such as mold spots, moldy odor, and water damages, were often associated with a higher risk of AR. Jaakkola *et al.*, in a 6 years population-based cohort study on prevalence of childhood AR in damp buildings, have observed a 50% increased risk of AR development for children living in these damp buildings, and an almost 100% risk under continuous exposure [8].

In addition, studies have indicated that mold and fungal growth constituted one of the major allergens produced by dampness. Investigation of indoor fungal level inside the homes with known signs of dampness have observed significant increase in concentration of fungal spores in the indoor ambient air [10,12,13]. Experimentations with mold and humidity manipulation highlighted humidity and dampness as a major growth factor for mold [13,14]. Examinations of fungal growth as potential allergens were also performed by numerous studies to validate the effects of fungus and mold on the development of AR [12]. In context of Taiwan's tropical climate and relatively high humidity, similar conclusion on indoor dampness and risk of AR could be drawn [18]. Studies have reported consistently higher prevalence of asthma, AR, and other respiratory health problem in children living under damp buildings in Taiwan [7]. Furthermore, the prevalence of the building dampness was observed to be as high as 72.3% of the study population [7].

Under the context of indoor dampness and fungal growth, it was supposed that the frequent use of bedroom shower produced high level of moisture and humidity inside the bedroom, and converted the bedroom into the ideal humidity condition for mold growth and propagation, greatly increasing the risk of mold growth. Contamination of the bedroom by mold growth could lead to the release of mold allergens. Constant exposure to fungal allergen greatly elevated the risk of AR development, especially in children [25–27]. Furthermore, fungal contamination of the bedroom could be extra hazardous in terms of exposure, as bedroom was typically one of the areas where most of the home occupants' time was spent. This hypothesis was supported by the logistic regression results with SFAR score and CFU level.

4.2. Frequent opening of windows and open hours

Beside dampness, ventilation habit was also observed in this study to be another important potential risk factor for AR. Logistic regression analysis have shown that frequent opening of windows decreased the prevalence of AR. The importance of ventilation and its role as a potential risk factor for AR development has been discussed extensively by many studies on environmental risk factors and indoor air quality. Sun *et al.* observed a decrease in prevalence of allergic symptoms as air exchange rate increased [23]. Bornehag *et al.* observed a dose–response relationship between low ventilation rate and prevalence of allergic symptoms, suggesting that low ventilation rate can be considered as a potential environmental risk factor for allergies [19].

Notably, the regression analysis results between CFUs level and window opening hours have suggested a positive correlation relationship between the two variables. This indicated that increasing hour of ventilation could in fact resulted in a higher level of mold present in indoor air, contrary to our hypothesis that longer ventilation hour could decreased the level of mold. Review of existing literature, however, supported this observation. In Chapter 3 of the WHO Guideline for Indoor Air (2009), the advantages and disadvantages of natural ventilation were outlined. One of the primary disadvantages highlighted was that, in geographical locations that have high humidity, natural ventilation could result in higher indoor moisture by letting moistures from the humid outdoor air into the house [18]. As it was difficult to control the flow of air with natural ventilation, it was likewise difficult to control the moisture being let into the indoor air [28]. Taiwan, being a tropical country, fitted into the category of a geographical location with high outdoor humidity. Since moisture was considered a major factor in contributing mold growth, longer ventilation hours in regions such as Taiwan could bring in considerable amount of moisture from outdoor air, turning the indoor air into favorable condition for mold growth. This could explain our observation of increasing ventilation hours with increasing levels of CFUs.

In summary, the use of natural ventilation as a means of eliminating indoor moisture should be cautiously considered and designed for regions with high humidity such as Taiwan. While natural ventilation could potentially alleviate AR risks, as shown in our observation, over ventilation in humid areas could lead to adverse effects such as increasing risks of mold growth indoor. WHO Guideline cautioned the employment of natural ventilation due to its difficulty in controlling airflow and moisture flow into the house, and suggested that in humid areas natural ventilation should perhaps be best used in conjunction with mechanical ventilation, such as air conditioners, mechanical fans, and dehumidifiers, which allowed the control of air exchange rate [18]. Further investigation is needed to determine the point of over-ventilation in tropical countries like Taiwan so as to maximize the advantage of natural ventilation, while avoiding taking in excessive moistures from ambient air.

4.3. Prevalence of AR and age

Examination of age and AR prevalence in our study population has revealed an inverse relationship between age and AR prevalence. It was observed that AR tended to be less prevalent in older age groups, while more prevalent in younger age groups. Cross-referencing with existing epidemiological evidence has revealed similar conclusions. Lundbäck (1998) has indicated that prevalence and increase in prevalence of both AR and asthma were primarily centered in children and young adults [19]. Barbee *et al.* assessed the skin prick test (SPT) reactivity to allergen of population, age older than 2, in Tucson, Arizona. SPT results suggested an age relation to prevalence of allergies, with the highest SPT reactivity peaked in the third decade of life [29]. Higher prevalence of AR cases in younger age group was a well-established clinical observation. Our observation of negative association between age and AR corresponded to existing epidemiological evidences.

4.4. Significance of household pet

The presence of pet has known to be common risk factors for AR and asthma. Lim *et al.*, in an investigation of HDM and cat allergen, have identified cat allergen to be significantly associated with prevalence of allergic respiratory symptoms [30]. Regression analysis results have shown significant association between pets and AR, which correlated with current scientific evidence. However, it should be noted that, after adjustment for confounders with multiple logistic regression, pet no longer shown any significance. Therefore, the validity of the pet as a potential risk factor is questionable.

4.5. Practical implication and significance

The increasing prevalence of AR around the globe has corresponded with a sharp increase in medical spending on treatment of AR and asthma. In Sweden, the total annual cost of AR was estimated to be about € 1.3 billion, which was approximately USD 1.44 billion [31]. In South Korea, Korean National Health Insurance Corp. (NHIC) database has estimated a total spending of USD 223.68 million annually, with an additional indirect cost of USD 49.25 million from productivity lost [32]. Within the US, the estimated average spending by AR patients was approximately 1–8 fold more than non-AR patients, with additional USD 3.5 million worth loss of productivity [33]. Furthermore, AR has also been known to increase the risk for development of psychiatric disorders, including anxiety, depression, and insomnia, leading to decreased quality of life and crippled social functioning ability [34].

With the burden of AR increases, it has become more and more imperative that risk factors for AR to be identified quickly, so as to formulate new preventative measures. With mold and indoor dampness now being identified as one of the major risk factors, the importance of identifying other potential sources of moisture became more and more relevant in allergies prevention. The identification of shower in the bedroom as a potential source of dampness was a significant find. This discovery between bedroom shower use with mold and AR could lead to development of new preventative measure, perhaps even the establishment of new architectural and home decoration guidelines to prevent construction of potentially hazardous building layouts. Furthermore, discovery on the negative correlation between frequent opening of windows/window open hours and AR have the potential to be developed as new relief methods for alleviating AR symptoms. However, caution should be exercised in developing methods such as natural ventilation as it might not be applicable in highly humid countries such as Taiwan, and adverse effects, such as increasing indoor moisture, could occurred in an environment with high outdoor moisture [18]. New guidelines on ventilation for highly humid countries should focused on determining the point of over-ventilation in order to maximize the therapeutic advantage of natural ventilation, while preventing excessive moistures from entering indoor.

In our cross-sectional, population-based study, we have identified use of bedroom shower as a potential source of indoor dampness. Frequent use of shower was believed to cause elevated moisture level in bedroom, increasing the risk of mold growth within the bedroom. In addition, window open hours and habit have been identified to alleviate allergic symptoms, but over-ventilation in tropical countries could result in elevated levels of mold growth due to outside moisture entering indoor. The identification of new indoor risk factors hold significant potentials in development of preventative guidelines, and the decrease in risk of allergic rhinitis could amount to significant decrease in economic burden of AR.

Conflict of interest statement

We declare that we have no conflict of interest.

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