Original Article

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Correlation between Novel Potential Indoor Risk Factors and Frequency of Doctor's Visit for Respiratory Problem in Taiwan's Tropical Environment

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Abstract

Background: With a global rising trend in prevalence of allergic diseases, more attention has been paid to investigation of environmental risk factors. Many risk factors have so far been identified. However, novel risk factors specific to Taiwanese environment and lifestyle were still relatively unknown.

Objective: To investigate the potential effects of a number of little-known indoor risk factors on the frequency of doctor's visit for respiratory problems in context of Taiwanese environment and lifestyle.

Methods: A cross-sectional, population-based study was performed on a 861 participants around Kaohsiung area, Taiwan. Survey investigation was employed to assess the household environment and the frequency of doctor's visit for respiratory problems.

Results: Participants who performed "daily cleaning" was shown to have a significantly ($p=0.007$) higher mean number of doctor's visits in comparison to those who did not. Similar observation was made for participants who periodically took out beddings ($p=0.042$). Age had a significant positive correlation (linear regression β 0.089) with frequency of respiratory problems.

Conclusion: The habit of daily cleaning was implicated as a potential indoor risk factor due to the unique nature of Taiwanese cleaning habit and close contact with cleaning supplies, which could serve as chemical irritants. Bedding takeout was predicted to be an indicator of chronic allergies rather than an actual risk factor. However, both were controversial in their role as potential indoor risk factor, and required further examination.

Keywords: Air pollution, indoor; Volatile organic compounds; Allergens; Asthma; Rhinitis, allergic, seasonal; Hypersensitivity; Environment; Fungi; Taiwan

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Introduction

In the past few decades, the medical and scientific communities have witnessed a worldwide rising trend in allergic diseases (*eg*, allergic rhinitis [AR] and asthma). Epidemiological studies around the globe have noted a significant increase in the prevalence of both AR and asthma. In the ARIA update from 2008, it

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was stated that approximately 400 million people round the globe suffered from AR, with up to 40% of AR patients also suffering from asthma comorbidities.[1] In Japan, prevalence of AR increased from 3.8% in 1984 to 32% in 2008; the prevalence of asthma was also increased from 4.6% in 1992 to 9.1% in 2008.[1] Likewise, in Thailand, the prevalence of AR rose from 37.9% in 1995 to 50.6% in 2008; the prevalence of asthma increased from 12.2% in 1995 to 14.5% in 2008.[1] A national study conducted in Taiwan from 2000 to 2007 showed that the prevalence rates of AR and asthma were 26.3% and 11.9%, respectively.[2]

With such a widespread prevalence and dramatic increase in frequency of respiratory allergies, it has increasingly become apparent that more effective countermeasures against allergic diseases are warranted. Many studies have looked to possible risk factors in household environment as key in the development of respiratory allergies. Furthermore, with the identification of new indoor risk factors, it is possible to develop novel preventative measures against respiratory allergies through elimination of these risk factors, and allows for development new guidelines on home improvement, building examination, and architectural construction to minimize the presence of potential indoor risk factors. With this in mind, this study aimed to investigate the relationship between the prevalence of upper respiratory problems and several potential indoor risk factors, both well-known and little-understood, with respect to Taiwan's tropical environment.

One such risk factor was indoor dampness, which has been characterized as a major contributor to development of AR and asthma. Review of literature revealed extensive focus on the association between indoor dampness and allergic diseases, including respiratory allergies such as AR and asthma.[3-8] Indoor dampness in the majority of the studies was characterized by several common signs, such as the presence of "mold spots," "water leakage," and "moldy odor," suggesting mold as a major allergen highly associated with dampness.[5,8,9] Previous studies on the correlation between indoor fungal level and home dampness supported such notion,[3] and examination under lab setting have further demonstrated humidity to be an important growth factor for mold.[10] In this regard, Taiwan, being a tropical island with heavy seasonal rainfall, has an average relative humidity of 70%–85% all year round in addition to its relatively warm temperature,[11] is an ideal place for fungal growth. In addition, an *en suite* bedroom, which is basically consisted of a bathroom and shower within the bedroom, is a popular and common architectural design in many Taiwanese household. While the majority of similar studies focused extensively on the aforementioned signs of dampness, the implication of presence of a shower in bedroom as a source of dampness, is not well-understood. It was predicted in this study that perhaps frequent use of bedroom shower could have generated a high level of indoor moisture, which when compounded with Taiwan's already high ambient humidity, would result in an environment highly susceptible to mold contamination.

In addition to bedroom shower, the role of wooden constructions and furniture in the development of respiratory allergies is likewise not well-understood as a potential indoor risk factor. Similar to the *en suite* bedroom, Japanese style wooden floor and wall are common sights in a significant portion of Taiwanese household, usually as living room decoration. In addition, wooden furniture, especially wooden wardrobe, is extremely commonplace in almost all Taiwanese homes, particularly being used as fixed, decorative wardrobe or chipboard (*ie*, particleboard) wood closet.

The role of wooden constructions and furniture as indoor risk factor is currently unknown. Two theories are proposed in this study. First, it is possible that, due to Taiwan's high average humidity, wooden material becomes highly susceptible to degradation and rot from constant exposure to moisture, making it highly susceptible to mold invasion and colonization. Second, previous studies on wooden furniture, particularly chipboard furniture, detected high emission of chemicals, including formaldehyde and other volatile organic compound (VOC), from the furniture.[12-15] Similar results were observed in wooden constructions and furniture with chemical coatings.[13,16] It can therefore be theorized that wooden constructions and furniture can also possibly serve as a source of indoor VOC.

Ventilation has also been shown in previous studies to demonstrate significant association with prevalence of AR and asthma.[17-20] Through experimental investigations, poor ventilation was found to significantly decrease the air flow between indoor and outdoor ambient atmosphere.[20] As a result, indoor airborne allergens such as mold spores or house dust mites (HDM) continue to be trapped inside the buildings, allowing triggers for respiratory allergies to prevail indoor. In contrast, improving air flow allows dispersal of indoor allergen, and corresponds with decrease in allergic symptoms. It was predicted that similar observations can be recreated in this study.

TAKE-HOME MESSAGE

- Ventilation has significant association with prevalence of allergic reaction and asthma.
- Participants with habits of daily cleaning and bedding take-out seem to have more frequent respiratory problems.
- Age has positive correlation with more frequent doctor's visit for respiratory problems.
- The presence of shower in the bedroom and opening of windows were not found to be associated with frequency of respiratory problems, although no concrete conclusion could be made on the cause yet.

Materials and Methods

Study Design and Sampling

A cross-sectional, population-based study was performed around Kaohsiung City, Taiwan in order to assess the potential effects of possible indoor risk factors on the frequency of physician office visit for respiratory problems. Respiratory problems in this case, was referred to various typical symptoms of AR and asthma, as described in the Score for Allergic Rhinitis (SFAR) by Annesi-Maesano, *et al.*[21] This included symptoms such as runny nose, sneezing, wheezing, and blocked nose, especially when the subject does not have any concurrent cold or flu. The participants were inquired about the number of visits to clinics or hospitals for any of the above-mentioned respiratory symptoms over the past three months before enrollment into the study. The number of visits was used as a surrogate for the frequency of respiratory problems. Comparison between potential indoor risk factors was made using this number.

The study population was randomly selected from people and their accompanying relatives willing to participate in this study, who attended Anshing Clinic, Kaohsiung, Taiwan. A team of researchers stationed at the clinic recruited for survey investigation individuals aged 20 years or older who had no major disabilities that hindered the understanding of the survey, in accordance to the Institutional Review Board regulations.

A total of 1009 participants was re-

cruited. Out of this 1009 participants, 11 were excluded due to being under the age of 20; an additional 137 participants were also excluded from the study for failing or declining to answer the number of visits made for respiratory problems over the past three months. This left 861 participants to be analyzed.

Survey Investigation

The survey investigation comprised of two parts. The first part was the assessment of participants' home environment. In this part, the participants were asked about the presence of bedroom shower and the frequency of shower usage, as well as signs of indoor dampness such as mold spots, water leakage, or moldy odor within their homes. Thereafter, the participants were inquired about their ventilation habit, such as whether they opened their home windows periodically and hours of ventilation. Participants were also asked about the presence of Japanese-style wooden wall or floor in their bedroom; as well as the presence of fixed, decorative wooden wardrobe or chipboard, also known as particleboard; and wood closets. Furthermore, participants were asked about several additional parameters including the participants' and their family's smoking habit, presence of pet or house plants, age of their current home, cleaning habit, and periodic bedding takeout.

The second part of the survey assessed the frequency of respiratory problems in terms of the number of doctor's visits. As stated above, respiratory problems were defined in this study by symptoms outlined in Annesi-Maesano, *et al.*[21] This included cough, wheezing, sneezing, and runny nose.[21] The participants were asked about the number of visits made to seek out medical attention for any of the respiratory symptoms listed above over a period of three months prior to the enrollment into this study. Additionally, the survey intentionally specified that the purpose for the doctor's visit should only be for respiratory symptoms, and that the symptoms should not be concurrent with non-allergic respiratory problems such as flu like symptoms.[21] This was done in accordance to the guideline laid down in Annesi-Maesano, *et al,* so that only doctor's visit for AR and asthma may be included in the study.[21] In addition, the participants' medical records from Taiwan's National Healthcare Insurance (NHI) were, with participants' permission, examined to validate the number of doctor's visits reported.

Ethics

This study was approved by the Institutional Review Board (IRB) of Kaohsiung Veterans General Hospital, Taiwan. All participants involved were presented with and signed an IRB-approved informed consent form.

Statistical Analysis

After survey investigation, participants were divided into two groups for each discrete independent indoor risk factor, usually by the presence of said variable (*ie*, "yes" or "no"). Because our data did not follow a normal distribution, median and interquartile range (IQR) were reported. Independent-sample Mann-Whitney U test was used to compare the number of visits between the two groups. To determine the correlation between the number of visits and each of age and number of windows, linear regression analysis was used. Multiple linear regression analysis was used to control for potential confounders. SPSS® (IBM Corp, New York, USA) was used for data analysis. A p value <0.05 was considered statistically significant.

Results

Out of the 861 participants included in this study, 62% were female (Table 1). The

Table 1: Frequency of studied variables in studied participants

Variable	n (%), (n=861)
Female sex	534 (62.0)
Diabetes mellitus	49 (5.7)
Hypertension	95 (11.0)
Mold spots	240 (27.9)
Water leakage	81 (9.4)
Moldy odor	94 (10.9)
Pet	217 (25.2)
Plant	155 (18.0)
Japanese style wooden floor or wall	270 (31.4)
Fixed decorative or chipboard wardrobe	505 (58.7)
Toilet in bedroom	391 (45.4)
Shower in bedroom	380 (44.1)
Windows in bathroom	332 (38.6)
Frequent use of bedroom shower	325 (37.7)
Frequent opening of windows	717 (83.3)
Daily cleaning	317 (36.8)
Bedding takeout	340 (39.5)
Smoke	315 (35.6)

mean age of the participants was 43.0 (SD 14.9) years. The mean age of participants' houses was 18.6 (SD 9.8) years. The mean number of doctor's visits made for respiratory problems during the past three months was 1.2 (SD 14.9, median 0). The mean number of windows in participants' home was 1.3 (SD 0.7, median 1). The windows were opened for a mean of 3.6 (SD 1.9, median 4) hours per day.

Those participants who performed "daily cleaning" had a significantly (p=0.005) higher median number of physician office visits compared to those who did not (Table 2). Similarly, those who performed frequent "bedding takeout" under the sun had a significantly (p=0.028) higher median number of doctor's visits for respiratory problems in comparison to participants who did not frequently take out their bedding to the sun (Table 2).

Among continuous indoor risk factors studied, age, dampness score, number of windows, window-open hours, and age of house, only age of participants was found to be significantly correlated (adjusted β 0.012) with the number of doctor's visits for respiratory problems (Table 3).

Discussion

Wooden Constructions and Furniture

Participants with fixed, decorative or chipboard wooden wardrobes in their home did not report a significantly higher number of doctor's visit than participants without the wardrobes. As it currently stands, the role of wooden wardrobe, as an indoor risk factor, was not well-understood, and the mechanism on how wooden wardrobe could affect development of respiratory allergies was currently unknown. Review of literature gave insights on two possible theories in regards to this question. First, it is possible that due to constant exposure to Taiwan's high average humidity and excessive moisture, wood degrades over time. Similar to degradation of building materials due to water damage,[7,9] the constant contact with high ambient humidity serves to erode and damage the wooden materials, making it susceptible to rot and mold invasion, eventually resulting in the wood furniture itself becoming a source of indoor mold allergens.

Second, previous studies into wooden furniture, particularly furniture made of chipboard materials or received special chemical coatings, show that they emit high levels of VOCs, including formaldehyde and di-2-ethylhexyl phthalate (DEHP).[13-15] In particular, chipboard, or as some studies referred to as particleboard, is identified by numerous studies

as a common source of indoor VOCs and formaldehyde emission.[12,14,15] Additionally, some studies on VOCs emission underscore the potential for furniture coatings to emit significant levels of indoor VOCs,[16] particular under highly humid conditions where water-solvent chemical coatings can be dissolved in and dispersed with the ambient water vapor. Considering Taiwan's high average humidity and commonality of chemically-treated furniture, mostly made up of low-quality chipboard panels, it can be inferred that wooden furniture would be a major source of indoor VOCs among Taiwanese households. Furthermore, investigations into the effects of common indoor VOCs on human health have revealed the highly irritant and toxic natures of certain VOCs such as DEHP and formaldehyde, making them potent triggers for respiratory allergies.[12,22,23] Further studies have also provided evidence on the roles of VOCs in development of respiratory allergies, particularly asthma, under prolong exposure.[12,22] Under these contexts, it is thus possible to suggest chipboard furniture as a potential source of indoor VOCs.

Nonetheless, so far, our current data failed to clearly support the two proposed theories. More studies are required to determine the actual nature of the relationship between wooden furniture and respiratory allergies. In addition, no significant difference was observed between the frequency of doctor's visits for respiratory problems and having a Japanese-style wood floor and wall. Interesting thought to be considered about wood floor and wall was that there exist some fundamental differences in either the constructions of or the materials used in wood floor and wall from those used for wood wardrobes. Considering the requirements for maintaining structural integrity of a building, it was possible that, instead of the less-robust chipboard panels, wood floor and wall were constructed using higher-quality

Table 2: The median (IQR) number of physician office visits for respiratory problems stratified by some variables

Variable	n	Median (IQR)	p value
Sex			
Male	327	0 (1)	0.060
Female	534	1 (1)	
Diabetes mellitus			
Yes	49	1 (3)	0.257
No	812	0 (2)	
Hypertension			
Yes	95	0 (2)	0.970
No	766	0 (2)	
Mold spots			
Yes	240	1 (2)	0.328
No	621	0 (2)	
Water leakage			
Yes	81	1 (2)	0.392
No	780	0 (2)	
Moldy odor			
Yes	94	0 (2)	0.485
No	766	0 (2)	
Pet			
Yes	217	0 (2)	0.475
No	643	0 (2)	
Plant			
Yes	155	1 (1)	0.903
No	705	0 (2)	
Japanese style wooden floor or wall			
Yes	270	0 (1)	0.277
No	591	0 (2)	
Fixed decorative or chipboard wardrobe			
Yes	505	1 (2)	0.072
No	356	0 (1)	

Continued

Table 2: The median (IQR) number of physician office visits for respiratory problems stratified by some variables

Variable	n	Median (IQR)	p value
Toilet in bedroom			
Yes	391	0 (2)	0.907
No	464	0 (2)	
Shower in bedroom			
Yes	380	0 (2)	0.883
No	472	0 (2)	
Windows in bathroom			
Yes	332	0 (2)	0.220
No	513	0 (2)	
Frequent use of bedroom shower			
Yes	325	0 (2)	0.733
No	399	0 (2)	
Frequent opening of windows			
Yes	140	0 (2)	0.352
No	717	0 (2)	
Daily cleaning			
Yes	317	1 (2)	0.005
No	540	0 (1)	
Bedding takeout			
Yes	340	1 (2)	0.028
No	517	0 (1)	
Smoke			
Yes	315	0 (2)	0.417
No	539	1 (2)	

wood panels or have received a more extensive preservative treatment to maintain the integrity of the structure, hence insusceptible to either of the proposed theories. Nonetheless, we do not have enough data yet to provide any definite conclusions on this issue. However, subsequent studies into understanding the typical construction process of the Japanese-style wood floor and wall are warranted in order to fully examine possible reasons for the discrepancies observed in this study.

Daily Cleaning and Bedding Takeout

In addition to fixed, decorative wardrobes and chipboard closets, participants who reported daily cleaning activities were observed to have a higher frequency of doctor's visit for respiratory problems. This was an unexpected finding as it was often logically assumed that with frequent cleaning one could decrease the level of indoor allergens, such as mold spores or house dust mites (HDM). Review of previous studies on the effects of cleaning likewise supported the same notion.[24,25] Hegarty, *et al*, investigated the effectiveness of conventional and filter vacuum cleaners in removing HDM, and reported lower concentration of HDM when either types of vacuum cleaners was used.[25]

Three possible explanations were proposed. First, the definition of term "cleaning" was not clearly outlined within this study. As such, "cleaning" could refer to a myriad of janitorial activities, from using vacuum cleaners to employing chemical cleaning reagents. In the latter case, it can be postulated that there was frequent contact with chemical reagents during the cleaning process, some of which were possible irritants.[26,27] In a study on the short-term respiratory effects of cleaning exposure, Medina-Ramon, *et al*, reported that exposure to diluted bleach, air freshener, and cleaning sprays is associated with aggravated respiratory symptoms.[27] Based on their findings, it can be suggested that the increased frequency of respiratory problems observed in our study was probably due to frequent contact with chemical cleaning reagents.

Second, as mentioned by Hegarty, *et al*, vacuum cleaning was capable of reducing

Table 3: The relationship between different continuous variables and average numbers of doctor's visit using univariate and multiple linear regression analyses. Multiple linear regression was adjusted for dampness score, number of windows, time windows were open, and age of house.

Variable	Unadjusted slope	Adjusted slope (95% CI)
Age (yrs)	0.007	0.012 (0.002 to 0.022)
Dampness score	0.015	-0.047 (-0180 to 0.086)
Number of windows	-0.025	-0.094 (-0.231 to 0.042)
Time windows were open (hrs)	0.018	-0.009 (-0.060 to 0.041)
Age of house (yrs)	0.011	0.002 (-0.009 to 0.012)

the concentration of HDM.[25] However, it should be noted that the majority of Taiwanese people still utilize the traditional broom as the preferred cleaning method. Using a broom, a large amount of dust often distributes during the cleaning process, resulting in the dispersal of high level of possible HDM in the indoor air. The use of a vacuum cleaner, however, could potentially negate such a problem as shown in Hegarty, *et al*. It was therefore believed that, the cleaning method commonly used in Taiwan perhaps results in more dispersal of indoor allergens instead of the removal of allergen seen in Hegarty, *et al*, and contributes to the increased incidents of respiratory allergies.

Finally, in addition to the use of brooms, Taiwanese janitorial work traditionally follows up broom-sweeping with mopping. It is possible that the mopping also has the unintended side effects of actively adding moisture to the indoor environment. Considering moisture and humidity are important growth factors for mold, the added moisture from constant mopping, in addition to Taiwan's already high ambient humidity, could make the indoor environment an ideal habitat for mold colonization, resulting in elevated indoor fungal level and increasing risk of triggering fungal allergies in the form of AR or asthma.

We found that participants who often took out their beddings under the sun had a higher frequency of doctor's visit for respiratory problems, which was again a surprising finding. Originally, it was thought that more bedding takeout would have actively eliminated potential allergens infested the bedding, such as mold spores and HDM, thus reducing the frequency of respiratory problems. It is unknown why the opposite results were observed. One possible explanation suggested that frequent bedding takeout is in fact an end-result rather than a causative factor. What this entailed was that, instead of assuming participants actively took out bedding to prevent accumulation allergens, it was in fact a reaction to an already allergen-infested environment. In other words, the bedding takeout was done in order to actively get rid of allergens instead of a preventative action, as previously thought. In this regard, frequent bedding takeout became an indicator of a highly allergic and problematic environment as opposed to a sign of improved indoor hygiene.

Nevertheless, it is currently not possible to draw any valid conclusion until more data are acquired. Therefore, more specialized studies are highly recommended to test the validity of each specific hypothesis mentioned above. It is also highly suggested that future studies in similar field focus on understanding Taiwanese cleaning habits and its fundamental differences to those of Western countries, as it is

highly suspected that differences in cleaning habits between Taiwanese and people of other regions would affect the status of indoor allergens differently.

Age and Frequency of Physician Office Visit for Respiratory Problems

Linear regression analysis showed that an older age was associated with increasing frequency of doctor's visit for respiratory problems. Cross-referencing with existing literature on the subject revealed similar observations. Settipane, *et al*, in a 23-year follow-up study on development of AR and asthma among college students, observed a continuous increase in frequency of AR and asthma as the students grew older.[28] Additionally, Burgess, *et al*, using data from 1968, 1974, and 2004, demonstrated persistence of childhood AR and asthma well into the middle ages.[29] Logically and clinically speaking, increasing age often corresponds to weakening of the immune system. Taking into account the fact that most of our study population was selected from age 20 and older, it was not surprising to see increasing frequency of doctor's visit due to weakening of the immune system as the participants became older. Therefore, age could not necessarily be considered a novel risk factor nor can it be actively negated as it was more or less a universal effect of the natural progression of human life.

Shower in Bedroom and Frequent Opening of Windows

Contrary to our previous prediction, participants with shower in their bedroom did not necessarily report a significantly higher frequency of doctor's visit for respiratory problems. It was originally theorized that the presence and constant use of bedroom shower could serve as a major source of indoor dampness, providing necessary moisture for mold invasion and colonization. It was further postulated that the colonization of the bedroom environment with mold would eventually constitute a major source of indoor fungal allergen, thus serving as an irritant and trigger for respiratory allergies. The lack of a significant increase in frequency of respiratory problems did not provide any supportive evidence, however. One possible explanation proposed was that the moisture contributed by the use of shower was probably not enough to increase the air humidity significantly in comparison to the high level of humidity already exist due to Taiwan's tropical climate. As stated before, Taiwan has an average relative humidity of 70%–85% all year round.[11] According to Block (1953), the relative humidity requirement for mold growth usually ranges from 65%–95%, depending on the materials.[10] The level of humidity in Taiwan is already well within the required level for mold growth. Any additional moisture, such as those from the use of shower, would not contribute to any significant effect. Needless to say, additional studies are required before a definitive conclusion can be made. It is highly recommended that primary focus of future studies should be placed on quantifying both indoor dampness and fungal level for bedroom with and without shower in order to more accurately compare the effects of shower use on indoor level of humidity.

Those study participants who claimed to frequently open their windows for ventilation were not observed to have a significantly lower frequency of doctor's visit for respiratory problems. It was originally expected that, with increased ventilation, there would be increased air flow in the house environment, allowing the dispersal of indoor allergens such as HDM or mold spores.[18-20] Lack of a significant difference between participants who did and did not frequently opened their windows failed to provide any concrete supports for our theory. Review of literature, how-

ever, provided some possible explanation for this observation. In Chapter 3 of the WHO Guideline for Indoor Air (2009), it is stated that in geographical regions where the ambient humidity is high, natural ventilation, which included window-opening, can be ineffective in clearing out indoor moisture, as opening the windows only let in excessive moisture from outside air.[20] With the humidity remaining indoor, mold and HDM can continue to propagate, resulting in zero improvement in the indoor allergen levels. Considering the high level of humidity in Taiwan, it is reasonable to suggest that a similar phenomenon has happened within our study. Instead of dispersing indoor allergens and moisture as expected, frequent opening of windows instead lets in more ambient moisture into the house, resulting in higher level of indoor dampness. This could explain the lack of significant difference in frequency of doctor's visit for respiratory problems between the two groups. However, more information is needed to further confirm the proposed explanation. Employing more accurate methods for quantifying air humidity level and air flow rate is highly recommended to obtain more precise data for validation of our theory.

Practical Implication and Significance

With the rising prevalence of respiratory allergic diseases such as AR and asthma around the globe, the socioeconomic burden, both directly and indirectly, from allergic diseases was likewise seeing an increasing trend across regions of the world. In the USA, it was estimated that the annual average medical spending by an AR patient is approximately 1–8 times higher than a non-AR individual.[30] South Korean National Health Insurance Corp. (NHIC) database has estimated a total annual spending of US$ 223.68 million on AR treatment, with an additional cost of US$ 49.25 million due to productivity lost, such as work absence and sick leaves.[31] The ARIA update in 2008 put estimated the total cost of asthma in Singapore and Korea to be about US$ 33.93 million and US$ 2.04 billion, respectively.[1] For Taiwan specifically, the National Health Insurance Research Database calculated the cost of asthma treatment to occupied approximately 26.5% of all health care expenditures.[32] Furthermore, the mean cost of hospitalization for asthma patients was 2.7 times higher than non-asthma patients.[32] In addition to financial costs, AR and asthma also cause considerable indirect social and psychological burden, with severely adverse side effects such as insomnia, depression, and performance impairment.[30]

Under such heavy socioeconomic burdens, it has become apparent more effective preventive measures are needed in order to successfully limit the prevalence of allergic diseases. In this regard, environmental risk factors, particularly those within common household, have become the key in the development of novel solutions for allergic diseases, and the identification of new indoor risk factors is now one of the core components to the success in preventing allergic diseases development. With the identification of additional indoor risk factors, new guidelines on home decoration, building inspection, and architectural construction could be designed to avoid or minimize the presence of potential risk factors, whether they are in building layouts, construction materials, or personal lifestyles.

In this context, our study results, with the exception of aging, were able to offer some new insights into the validity of several novel little-understood potential risk factors, in addition to other well-known risk factors. We also provided additional information about the potential effects of these suspected indoor risk factors in terms of Taiwan's unique tropical environment. The significance of daily cleaning

habits may be indicative of some inherent flaws in the traditional Taiwanese janitorial methods that unexpectedly contributed to frequent respiratory allergies. Finally, while our findings could not necessarily established concrete conclusions on the cause and effect of the proposed risk factors, they have provided evidence into possible correlation between respiratory allergies and other previous-unknown risk factors, thus opening up new directions for future studies.

Limitations and Future Directions

One of the major limitations this study suffered from was its format. As this investigation was primarily based on survey investigation over a broad range of potential risk factors, it was only possible to make basic preliminary observations based on comparison of the distribution of the number of doctor's visit for respiratory problems between various variables. For the most part, our results only determined which risk factor was significantly associated with the frequency of doctor's visit. We then made predictions and conclusions based on our results in order to proposed potential explanation for our observation. An example included our proposed hypothesis that daily bedding takeout was an indication of pre-existing allergies rather than an actual risk factor. However, without additional experiments to properly and accurately assess the allergic status of the participants, our observation was incapable of establishing concrete relationship between bedding takeout and allergies. Similarly, our hypothesis for indoor moisture and shower, window opening and HDM, bedding takeout, and cleaning habits still requires additional studies with improved quantitative techniques and methods to be properly validated. Nonetheless, the main purpose of this study was to perform a preliminary screening to identify any potential novel risk factors relevant to Taiwanese environment and lifestyle. To this end, our observations provided potential insights that could be followed on in more in-depth specialized future investigations.

The second major limitation of our study was the self-reporting nature of the survey. The survey was designed based on guidelines provided by Annesi-Maesano, *et al*,[21] for quantification of the frequency of respiratory problems in terms of doctor's visit. Deliberate attempts were also made to clarify our definition of respiratory problems based on symptoms outlined by Annesi-Maesano, *et al*, and to separate allergic respiratory symptoms from those of non-allergic nature, such as viral or bacterial upper respiratory infections. Cross-referencing with NHI online database was also done to validate the participants' answer. While this action indeed for the most part removed non-allergic respiratory disorders, the similarity in symptoms between a common cold and an allergic respiratory response meant that the participants, who were mostly untrained in medical knowledge, might sometimes have difficulty distinguishing the two disorders, especially when infections and allergies only produced minor symptoms. Two methods could have been employed to prevent potential errors like this. One was to greatly increase the sample size in order to statistically minimize the risk of misidentification. The second method was to supplement survey investigation with additional validation methods, such as IgE or Phadiotop test, to secure more concrete and accurate data on the participants' allergic status.

Finally, there might also be additional confounding variables that were not considered in this study. For one, we observed the participants with shower in their bedroom lacked any significant difference regarding their distribution in the frequency of doctor's visit for respiratory problems

than participants without shower. To this, we proposed that Taiwan's ambient moisture was high enough for indoor mold growth that any additional moisture produced by bedroom shower would be an insignificant contribution. Nonetheless, we failed to account for the presence of other confounders such as the dehumidifiers within the bedroom alongside the shower. The unaccounted presence of the dehumidifier could explain the lack of significant difference in frequency of respiratory problems as the moisture was likely removed, thus reducing the shower's contribution to indoor moisture markedly. The potential existence of unaccounted confounders could greatly influence the study results. Therefore, the future investigations should be designed to better identify confounders.

In conclusion, our study results suggested that participants with habits of daily cleaning and bedding takeout seem to have more frequent respiratory problems. The cause of such findings is currently unknown, although several theories were discussed. Age was found to be positively correlated with more frequent doctor's visit for respiratory problems, which corresponded with existing epidemiological observations. The presence of shower and opening of windows were not found to be associated with frequency of respiratory problems, although no concrete conclusion could be made on the cause yet. Finally, it was believed that the current findings provided interesting insights on novel indoor risk factors. Future studies with more precise data acquisition are highly warranted to validate the probable underlying cause and effect of the risk factors discussed in this study.

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