Home characteristics are associated with indoor microbial exposures in subtropical homes

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ABSTRACT

Research has suggested associations between indoor microbial exposures and respiratory diseases across the globe. This aim of this study was to examine whether microbe levels were associated with housing characteristics. Study homes were selected from a prior citywide survey, and housing characteristic questionnaires were distributed afterwards. Airborne fungi, bacteria and dust samples were collected. Samplings were conducted every month for a year. Having pets at homes and age of the house were found to affect the indoor concentrations of *Der p 1* and *Der p 2*. After controlling for the potential influence of outdoor fungi, levels of indoor total fungi appeared to be associated with the presence of water stagnation in homes. Future research may further endeavour to clarify the basics of aerobiology to identify exact factors and mechanisms contributing to the elevated microbial concentrations and study them as a function of various housing characteristics to formulate effective environmental guidelines for healthy buildings.

INDEX TERMS

Home characteristics; Fungi; Bacteria; *Der p 1*; *Der p 2*

INTRODUCTION

The well-known indoor allergens associated with allergic disease include house dust mite, dander from pets, cockroaches and fungal allergens (Luczynska *et al*., 1990; Pollart *et al*., 1991). Epidemiological studies have identified damp living conditions as a major risk factor for respiratory symptoms in children (Spengler *et al*., 1994; Tsuang *et al*., 2003). In addition, the fact that fungi and house dust mites prosper in damp conditions has been established (Harving *et al*., 1993), and the association between fungi and elevated respiratory allergy and asthma has been demonstrated (Peat *et al*., 1998). Exposure to house dust mite allergens such as *Der p 1* or *Der p 2* is also an important risk factor for asthma (Van Der Veen *et al*., 2001). A long-term study has shown that exposure to low levels of mite allergens in bedroom is associated with decreasing bronchial hyper-responsiveness in sensitized asthmatic subjects under optimal drug treatment (Maestrelli *et al*., 2001).

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The airborne fungi concentrations in tropical countries were higher than those in temperate zones (Su *et al*., 2001), and such findings have highlighted the need to critically evaluate the approaches to reduce indoor fungal exposure. Some studies had suggested an association between indoor microbial concentrations and selected home characteristics (Chew *et al*., 1998; Dharmage *et al*., 1999). However, data and pattern of associations were not as conclusive in this region where overall high levels of indoor microbes have been observed. The aim of this study was, therefore, to examine whether microbial levels were associated with home characteristics.

METHODS

Study homes were selected from a prior citywide survey, and a total of 33 houses were included. A self-administered questionnaire was used to collect information including the age, construction, number of rooms, type of ventilation, use of air filter, evidence of dampness and moulds, bedding and cleaning routines, presence of pets and cooking habits in these homes. Samplings were conducted every month over a year. The sampling procedure has been described elsewhere (Su *et al*., 2001). Airborne viable bacteria and fungi were collected using a Burkard sampler. Yields of colonies and genera were identified according to the morphology after incubation and the concentration was presented in terms of colony forming units per cubic metre. Dust samples from a child's mattress were collected by a hand-held vacuum cleaner with a glass fibre filter. *Der p 1* and *Der p 2* in dust were measured by ELISA.

The allergen level distribution was first assessed with the Shaporo–Wilk normality test. The lack of general normality resulted in the adoption of the Mann–Whitney test to explore the association between allergen levels and home characteristics. Statistical analysis was performed using the JMP software, version 3.2 (SAS Institute, Cary, NC, USA) and STAVIEW (Abacus Concept, Inc).

RESULTS

The home characteristics of the 33 houses are shown in Table 1. The associations between various microbial concentrations, by seasonal and annual average, with individual home characteristic are summarized in Table 2. The factor of having pets at homes was significantly associated with higher concentrations of *Der p 1* and *Der p 2* (median of 7.113 versus 2.947 µg/g for *Der p 1*, and 2.132 versus 1.032 µg/g for *Der p 2*), only in spring. In summer, homes older than 10 years were found to have lower concentrations of *Der p 1* (median of 1.264 versus 5.942 µg/g) and *Der p 2* (median of 0.455 versus 1.483 µg/g), but higher *Der p 1* concentrations (median of 9.183 versus median of 2.135 µg/g) in autumn. The homes with prior water stagnation had lower *Der p 1*concentration (median of 0.337 versus 3.187 µg/g). Higher *Der p 2* concentrations were seen in homes with an air conditioner in the child's bedroom (median of 153.911 versus 71.436 µg/g) in winter.

In autumn, the factors that associated with total fungi concentration included mould. The presence of mould growth (median of 12348 versus 7195 CFU/m^3), and absence of dehumidifiers (median of 9818 versus 2797 CFU/m^3) appeared to be associated with higher levels of total fungi. When individual genus was analysed, *Aspergillus* levels seemed to be associated with most home characteristic of interest. Yet, *Cladosporium* concentrations were found to be associated only with the building type, mould presence and use of dehumidifier, *Penicillium* concentrations were associated with the use of air conditioner and presence of pets in the home, and Yeast concentrations with water stagnation mould presence, and the use of dehumidifiers. Indoor bacterial levels were only affected by the presence of pets in homes, among all characteristics examined.

Table 1 The home characteristics of the 33 houses

Characteristics	*n*	Characteristics	*n*	Characteristics	*n*
The age of house		Water stagnation		Use of air filter	
≤10 years	17	Yes	6	Yes	4
>10 years	16	No	26	No	28
House construction		Mould presence		Use of dehumidifier	
Apartment	13	Yes	13	Yes	5
Detached house	19	No	20	No	28
Room numbers		Use of air conditioner		Presence of pets in home	
≤4	6	Yes	20	Yes	10
>4	27	No	12	No	23

Table 2 The significant association found between home characteristics and microbial levels of seasonal and annual average (Mann–Whitney test, $p < 0.05$)

	Spring	Summer	Autumn	Winter	Annual
Building type			*Aspergillus*		
The age of the house		*Der p 1* *Der p 2*	*Der p 1*		*Aspergillus* *Der p 2*
Water stagnation		*Der p 1*	Yeast		
Mould presence			Total CFU *Cladosporium* Yeast		
Use of air conditioner			*Aspergillus*	*Der p 2*	
Use of air filter			*Aspergillus*	*Aspergillus* *Alternaria*	*Aspergillus*
Use of dehumidifier			Total CFU *Cladosporium* Yeast		
Presence of pets in the home	*Der p 1* *Der p 2*		*Penicillium*	Bacteria	Bacteria

It is known that the distribution of indoor fungal propagules was often a good reflection of outdoor intrusion (Wickman *et al*., 1992). We calculated the ratios of indoor to outdoor concentrations for partial control of influence of outdoor air (Table 3) to further clarify the effects of various home characteristics. Prior presence of water stagnation was associated with indoor fungi concentrations, especially in autumn (I/O = 2.2), indoor bacteria in winter (I/O =

3.06), and yeast in autumn (I/O = 2.2). Mould presence was associated with total fungi in fall (I/O = 1.28). In addition, mould presence was associated with the annual average concentration of yeast (I/O = 3.03). Use of air conditioners and dehumidifiers seemed to increase the concentrations of *Penicillium* and yeast, and use of air filters decreased the *Aspergillus* concentrations (I/O = 1.45).

Table 3 Significant association between home characteristics and indoor to outdoor (I/O) ratios of seasonal and annual average of microbial concentrations (Mann–Whitney test, $p < 0.05$) (median ratio of homes reporting the characteristic/median ratio of homes not reporting the characteristic)

	Spring	Summer	Autumn	Winter	Annual
Water stagnation (Y/N)	Total CFU (0.47/0.88)		Total CFU (2.20/0.76) Yeast (6.35/0.94)	Bacteria (3.06/1.23)	
Mould presence (Y/N)			Total CFU (1.28/0.69) Yeast (3.51/0.49)		Yeast (3.03/0.97)
Use of air conditioner (Y/N)				*Penicillium* (1.09/0.54)	
Presence of pets in the home (Y/N)			*Cladosporium* (0.57/0.90)		

DISCUSSION

Other studies suggest that the presence of water stagnation and mould growth may be associated with indoor fungal levels, and a previous study has also identified that large airborne fungal spore concentrations were linked to water intrusion and failure to remove indoor mould growth (Garrett *et al*., 1998). Mechanistically, presence of water stagnation and mould growth is a logical index of overall damp condition in homes, and an optimal environment for sustaining viable fungal propagation. Our study has also observed lower fungal levels in the homes with pets. This finding is consistent with the study by Verhorff *et al*. (1994), but contradictory to others (Dharmage *et al*., 1999). Various rationales have been proposed for either finding; for example, house pets tend to bring in more outdoor-generated fungi through their activities. Our household background is not necessarily identical to either scenario, and further examination of these study homes is warranted to clarify the most plausible rationale.

Research has also suggested that air conditioning might be an effective tool in reducing airborne fungi in residential environments (Garrison *et al*., 1993), which has not been seen in our study homes. In this part of the country, the climate with an average temperature of 22.5°C and relative humidity of 63.3% in winter does not entail the need to operate air conditioners after the autumn. However, the windows tend to be closed tight in winter. The accumulation of contamination of *Penicillium* on the device is likely to be brought inside by natural ventilation. Consequently, the lower air exchange rate could be the cause of the rising indoor concentrations of *Penicillium*.

Our study has observed lower *Der p 1* levels in bed dust from homes older than 10 years, a finding different from previous studies (Luczynska *et al*., 1998; Dharmage *et al*., 1999). However, it should be noted that potential confounders such as age of the mattress, type of quilt and frequency of vacuum cleaning, could not be adequately compared among these studies, and have not been taken into account in the current analysis. One could also consider whether asthmatic children resided in these older homes and, therefore, their beddings have been better cleaned than usual.

CONCLUSIONS

This preliminary study has been completed with limited sample size and yet, resulted in many significant observations for homes in this part of the world. From a public health perspective, we would at least encourage in-depth remedial actions for prior water stagnation and the removal of visible mould growth at homes even before further basic research is performed to demonstrate the underlying mechanism.

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