

Residential characteristics influence Der p 1 levels in homes in Melbourne, Australia

S. DHARMAGE*, M. BAILEY*, J. RAVEN†, A. CHENG‡, J. ROLLAND‡, F. THIEN§, A. FORBES*, M. ABRAMSON* and E. H. WALTERS†

Departments of *Epidemiology & Preventive Medicine, †Respiratory Medicine, ‡Pathology & Immunology and §Allergy & Clinical Immunology, Monash Medical School and Alfred Hospital, Prahran, Victoria, Australia.

Summary

Background Exposure to house dust mite (HDM) allergens is an important risk factor for childhood asthma. Knowledge of environmental determinants of HDM allergen levels is essential before designing rational avoidance measures.

Aim To investigate the effect of domestic characteristics on HDM allergen (Der p 1) levels in Melbourne homes.

Methods Dust was collected from bed and floor of the bedrooms in 485 houses over a period of one year. Dust was analysed for Der p 1 levels using an enzyme-linked immunosorbent assay. Temperature and relative humidity were measured at the visit. Details of residential characteristics were collected using a questionnaire. Statistically significant predictors of Der p 1 levels ($P < 0.05$) were identified using multiple linear regression.

Results High levels of Der p 1 were observed in the floors (geometric mean 17.2 $\mu\text{g/g}$ fine dust) as well as in the beds (geometric mean 20.3 $\mu\text{g/g}$ fine dust). Der p 1 levels in the floor dust were significantly lower in winter and spring. They were higher in houses built before 1980 and those with central heating, weather board walls, damp bedrooms or fitted old wool carpets. Der p 1 levels in bed dust were significantly higher in houses built before 1980, with wooden floors built on stumps, with high relative humidity, with visible mould in the room, in beds with an old mattress or in beds without a quilt.

Conclusions We would encourage construction of homes without carpets, wooden floors on stumps or weather board walls.

Keywords: allergens, house dust mite, indoor environment

Clinical and Experimental Allergy, Vol. 29, pp. 461–469. Submitted 1 April 1998; revised 28 May 1998; accepted 27 July 1998.

Introduction

Exposure to (house dust mite) HDM allergens is an important risk factor for childhood asthma [1,2]. Avoidance of exposure to these allergens has been shown to reduce bronchial hyperreactivity and asthma symptoms [3,4].

The concentration of HDM allergen in Australian homes is amongst the highest in the world [5]. This may be one plausible explanation for the higher prevalence of asthma in Australia compared with many other countries [6]. This

hypothesis is supported by two parallel observations of an increase in the concentration of house dust mites in Australian homes [7] and in the prevalence of asthma in Australia over the last few decades [8].

In Australia, *Dermatophagoides pteronyssinus* is the most commonly isolated species of HDM and therefore the source of the major allergen of interest (Der p 1). Knowledge of environmental determinants of Der p 1 levels is essential in designing rational avoidance measures to reduce these levels. Residential characteristics are thought to be important in controlling indoor allergen levels. Relative humidity, ventilation and fitted carpets have been repeatedly shown to influence HDM allergen

Correspondence: S. Dharmage, Department of Epidemiology & Preventive Medicine, Monash Medical School, Alfred Hospital, Prahran, Victoria 3181, Australia.

levels in homes [5,9–14]. However, the findings with respect to temperature [10,15], age and structure of the house [9,14], central heating [15], type of carpets [16], and bedding [17] are contradictory. Most of these factors are interrelated, as well as being related to other residential characteristics which may influence the HDM allergen levels. Some of these studies have examined one or only a few relevant factors together, hence the results may have been confounded by other unmeasured factors. The relationship between housing conditions and infestation by HDM is thought to be very different depending on the geographical area under study [11]. This, in combination with the high asthma prevalence and high HDM allergen levels in Australia, warranted further local research.

Hence, a cross-sectional study was carried out to assess the influence of residential characteristics and cleaning practices on HDM allergen levels in Melbourne homes.

Materials and methods

Subjects

Subjects were participants in a follow-up study to the European Community Respiratory Health Survey (ECRHS) in Melbourne. The sampling procedure has been described elsewhere [18,19]. Briefly, a questionnaire was mailed to a group of young adults, who were randomly selected from the electoral roll, during the first phase of the ECRHS survey which was carried out in 1992. This comprised 4500 subjects aged between 20 and 44 years, of whom 3200 (72%) responded. A random sample ($n = 1642$) and a symptomatic sample ($n = 433$) of the respondents were invited to the laboratory for testing in the second phase. A total of 757 subjects attended between 1993 and 1994. This group was asked to participate in a follow-up study in 1996 and 485 did so.

In the follow-up, participants were visited at home to collect dust samples from their bedrooms and residential information via a questionnaire. Then the participants were again requested to visit the laboratory to complete a detailed respiratory questionnaire, skin prick tests and lung function tests, which will be reported later (manuscript in preparation). This paper presents a cross-sectional analysis of the residential characteristics associated with the Der p 1 levels in the bedrooms of the participants.

Questionnaire

An interviewer-administered questionnaire was used to collect information about such residential characteristics as age of the home, type of construction, ventilation, heating, evidence of damp and mould, floor covering, bedding and cleaning routines.

Bedroom air temperature and relative humidity were recorded at the same visit using a digital thermohygrometer (Type THG-388 RS Components, China). The thermohygrometer was placed in the bedroom, 1 m above the floor level and away from windows, beds and heat sources and read 15 min after the meter was switched on.

Collection of dust samples

Samples of house dust were collected from the bed and the floor of the bedroom of the study subjects. These were collected using a modified Makita 4071D handy-vac (7.2 V, battery operated) with a 25 μm nylon filter, according to a standard protocol [20] with some modification. The modification was identified from a pilot study in which some of the floor dust samples collected from 1 m^2 were inadequate for the allergen assay. We found that at least 30 mg of total dust needed to be collected as each assay required around 10 mg of fine dust. Hence the bedroom floor was sampled according to two protocols. The standard protocol was to vacuum for a total of two minutes over an area of 2 m^2 adjacent to the side of the bed on which the participant slept. The extended protocol was followed if the dust collected according to the standard protocol seemed inadequate. In the extended protocol, vacuuming was extended by 1 m^2/min until an adequate sample was collected. The bedding was vacuumed for a total of 1 min to include the top of the mattress, under-blankets, quilt and/or upper blankets and the pillow.

Three trained researchers were involved in the home visits. Each home visit was made by two researchers. One collected the dust while the other administered the questionnaire; both were unaware of the clinical status of the participant, thus minimizing any interviewer bias.

Adequate bed dust for the allergen assay was collected from all houses ($n = 485$) in the study. Adequate floor dust was collected from 440 houses after vacuuming according to the standard protocol and the extended protocol was followed to collect adequate dust from the remaining 45 houses.

Measurement of Der p 1 levels

The samples were stored at 4°C for a maximum of 1 week, until they were processed in batches. They were extracted by borate buffer (pH = 8.0) and analysed for the major HDM allergen Der p 1 using a standard enzyme-linked immunosorbent assay (ELISA) [21,22]. The extraction temperature was 4°C and the ratio of dust weight to buffer was 0.1 gram/2 mL. The validity and repeatability of the test was examined with each batch processed using a World Health Organization standard HDM extract. The minimum detection level of Der p 1 was 0.2 $\mu\text{g/g}$ of fine dust.

The researcher involved in Der p 1 analysis was blinded to the clinical status and information from the home visit report to prevent any reporting bias.

Bed Der p 1 levels were expressed as $\mu\text{g/g}$ of fine dust. Floor Der p 1 levels were expressed as $\mu\text{g/g}$ of fine dust as well as $\mu\text{g/m}^2/\text{min}$.

The floor samples collected using the standard protocol had significantly higher Der p 1 levels ($20.7 \mu\text{g/g}$ of fine dust) compared with those using the extended protocol ($3.4 \mu\text{g/g}$ of fine dust). The correlation between floor Der p 1 levels expressed as $\mu\text{g/g}$ of fine dust and $\mu\text{g/m}^2$ was strong and significant for the samples in both the standard ($r=0.9$; $P<0.001$) and extended protocols ($r=0.8$; $P<0.001$). Hence, further analysis was carried out only on the Der p 1 levels expressed as $\mu\text{g/g}$ fine dust.

Analysis

The Statistical Analytical System package [23] was used to analyse the data. The distribution of the house dust mite allergen levels was positively skewed, hence log-transformed data were used in the analysis.

In the univariate analysis, Pearson correlation coefficients and simple linear regression were examined to assess the association between Der p 1 levels and other continuous variables. Analysis of variance was carried out to assess the association between Der p 1 levels and categorical variables.

Predictors of Der p 1 levels in bed and floor were examined separately. Season, temperature and relative humidity in the bedroom, type of house, year of construction, type of construction, base structure of the building, presence of a crawl space, central heating, air conditioning, level of the bedroom, observed damp patches and mould in the bedroom were considered as possible factors influencing both bed and floor Der p 1 levels. Variables considered only for bed Der p 1 were type and size of the bed, having a quilt or blankets on the bed, washing practices for bed linen and vacuuming of the bed. Variables considered only for floor Der p 1 were fitted carpet, type and age of the carpet, vacuuming practices for the floor and window dressings.

Multiple linear regression was carried out to identify the significant independent explanatory variables for the variance in Der p 1 levels after accounting for the effects of other relevant factors. Variables which were significant at $P<0.2$, exhibited a large effect in the preliminary analysis or those previously described as important in influencing the Der p 1 levels were included in the model. Then variables which were not significantly ($P<0.05$) associated with Der p 1 levels were excluded manually in a stepwise manner. In addition, an exploratory analysis was carried out to assess the possible confounders of the variables which were only significant either in univariate or multivariate analyses. The

geometric means for the identified predictors adjusted for the others in the model, relative humidity and temperature were computed using least square means method [23], in an analysis of co-variance (ANCOVA).

Ethics

The study was approved by the Ethics Review Committee at the Alfred Hospital. Written informed consent was obtained from all the participants.

Results

Very high levels of Der p 1 were observed in our sample of Melbourne homes. The geometric mean Der p 1 level (range of Der p 1 levels) for beds was 20.3 (range $0\text{--}361$) $\mu\text{g/g}$ of fine dust and for floors was 17.2 (range $0\text{--}691$) $\mu\text{g/g}$ of fine dust. The correlation between the bed and floor Der p 1 levels was modest, but statistically significant ($r=0.3$, $P<0.001$). We observed Der p 1 $>2 \mu\text{g/g}$ of dust in 90.3% of the bedroom floors and 96.9% of beds. Seventy-six percentage of the floors and 77% of the beds had Der p 1 $>10 \mu\text{g/g}$ of dust.

Bed Der p 1 levels

The mean temperature was 18°C ($\text{SD}=3$; range = $10\text{--}31$) and the mean relative humidity was 60% ($\text{SD}=8.6$; range = $32\text{--}80$). Ninety five percentage of the houses had a relative humidity of $>45\%$.

We observed a weak but significant positive correlation between bed Der p 1 levels and indoor relative humidity ($r=0.2$; $P<0.001$). We also observed a weak but significant negative correlation between indoor temperature ($r=-0.1$; $P=0.002$) and bed Der p 1 levels. The indoor temperature and relative humidity were negatively correlated ($r=-0.4$ $P<0.001$). The negative association between temperature and Der p 1 levels was found to be due to confounding by relative humidity in the multiple regression analysis. The positive association between relative humidity and bed Der p 1 levels remained significant after adjusting for temperature in the regression analysis.

Figure 1 shows the mean bed Der p 1 levels in different categories of temperature and relative humidity. Mean Der p 1 levels increased with increasing relative humidity in all the categories of temperature. The increasing temperature seemed to decrease the mean Der p 1 levels when the relative humidity was less than 65%. However, this interaction between temperature and relative humidity was not statistically significant ($P=0.08$).

We observed lower bed Der p 1 levels during winter and spring, but this *post hoc* difference was not statistically significant ($P=0.3$).

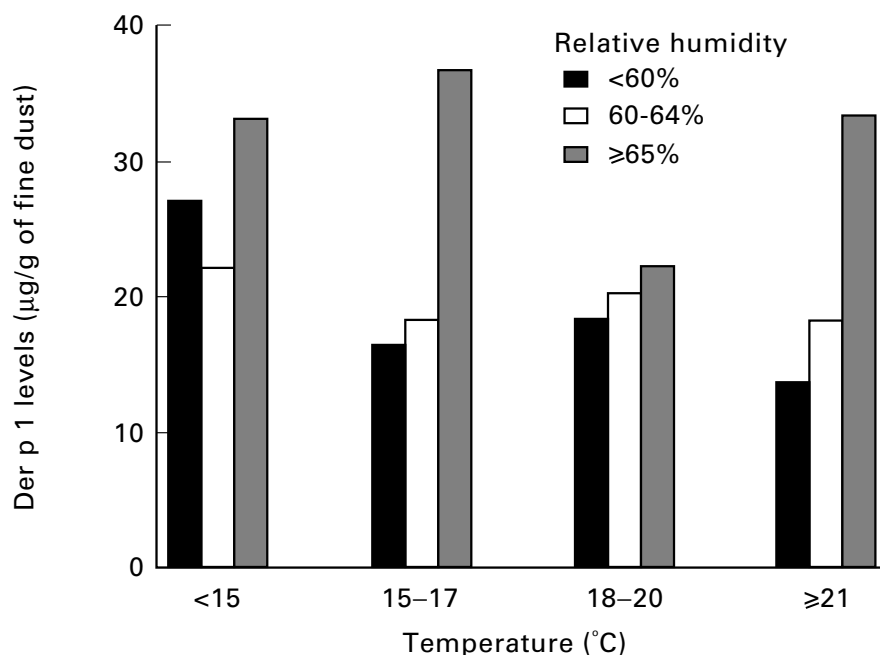


Fig. 1. Geometric mean Der p 1 levels in bed dust by temperature and relative humidity.

Table 1 describes the geometric mean bed and floor Der p 1 levels for the residential characteristics which were significant at $P < 0.05$ level, in the univariate analysis. Free standing homes were found to have 1.2-fold higher bed and 1.5-fold higher floor Der p 1 levels compared with other types of homes. Bedrooms on the ground floor had 1.9-fold higher bed Der p 1 levels compared with those on upper floors. Both these associations were found to be confounded by the age of the house in further evaluation. Houses built before 1980 had 1.7–2.9-fold higher bed Der p 1 levels compared with houses built in or after 1980. A higher proportion of houses

built in or after 1980 had bedrooms on an upper floor and were less likely to be free standing, compared with the houses built before 1980.

Houses with a crawl space under the floor had 1.4-fold higher bed Der p 1 levels compared with houses without a crawl space (Table 1). However, this effect was found to be due to confounding by the base structure in the multiple regression analysis. A higher proportion of houses with a crawl space had a base structure of stumps with wooden flooring. Houses built on stumps with wooden flooring had 2.1-fold higher floor Der p 1 levels compared with other base structures.

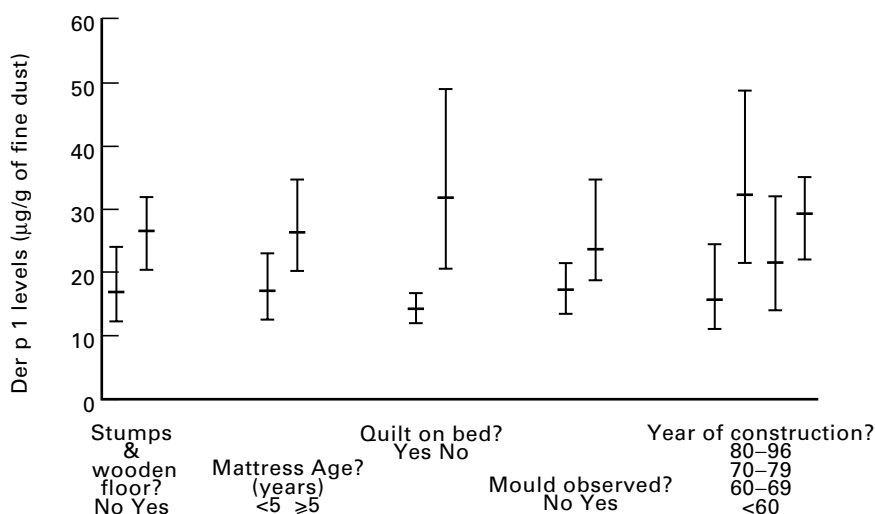


Fig. 2. Predictors of bed Der p 1 levels. Geometric means & 95% CI adjusted for other predictors and relative humidity.

Table 1. Mean Der P 1 levels by categories of the residential characteristics which were significant at $P \leq 0.05$ in the univariate analysis.

	No. of homes	Geometric mean Der p 1 levels ($\mu\text{g/g}$)	
		Bed	Floor
<i>Type of house?</i>			
Free standing	388	21.2*	19.1*
Attached	96	17.2	12.4
<i>Year of construction?</i>			
< 1960	343	23.5*	19.1
1960–69	39	13.9	15.4
1970–79	42	18.0*	15.4
1980–96	61	8.0	13.9
<i>Base of the bedroom?</i>			
Wooden on stumps	358	23.8*	17.2
Other	126	11.2	15.4
<i>Presence of a crawl space?</i>			
Yes	323	21.2*	19.1
No	161	15.4	15.4
<i>Level of the bedroom?</i>			
Ground	401	23.5*	17.2
Upper	84	12.5	13.9
<i>Presence of central heating?</i>			
Yes	264	21.2	21.2*
No	221	21.2	15.4
<i>Observed damp patches?</i>			
Yes	125	29.0*	23.5*
No	359	17.2	15.4
<i>Observed mould?</i>			
Yes	176	29.0*	21.2*
No	308	17.2	15.4
<i>Extractor fan over cook-top?</i>			
Yes	377	19.1	19.3*
No	101	23.3	12.5
<i>Heavy window drapes?</i>			
Yes	273	21.2	19.1*
No	212	19.1	15.4
<i>Venetian blinds?</i>			
Yes	67	21.2	10.1*
No	418	20.3	19.1
<i>Fitted carpet?</i>			
Yes	416		21.2*
No	79		5.7
<i>Type of carpet?</i>			
Wool	69		32.1*
Other	416		15.4
<i>Age of carpet? (years)</i>			
< 1	16		4.5*
1–5	93		19.1
> 5	299		20.2

Table 1. continued.

	No. of homes	Geometric mean Der p 1 levels ($\mu\text{g/g}$)	
		Bed	Floor
<i>Age of the mattress? (years)</i>			
≤ 5	179	15.4*	
> 5	305	23.5	
<i>Quilt on bed?</i>			
Yes	451	19.1*	
No	33	48.4	
<i>Blankets on bed?</i>			
Yes	115	26.1*	
No	369	19.1	

* $P < 0.05$ compared with the last category in the variable. Numbers do not add up to 485 in some variables due to missing information.

Having either a quilt or a blanket on the bed was found to significantly influence the Der p 1 levels in bed dust (Table 1), but only a quilt was found to be an independent predictor of bed Der p 1 levels.

The significant ($P < 0.05$) predictors for bed Der p 1 levels in the multiple regression analysis were indoor relative humidity, age and the base structure of the house, age of the mattress, presence of a quilt on the bed and observed mould in the bedroom. No other variables achieved a P -value of less than 0.1.

Figure 2 describes the geometric mean Der p 1 levels for each category of significant predictors adjusted simultaneously for the other predictors in the model, relative humidity and temperature. A higher bed Der p 1 level was observed in houses built before 1980 and those built on stumps with wooden flooring. The bed Der p 1 level was also higher if there was no quilt on the bed, the mattress was more than 5 years old or the participant had observed mould in the bedroom. The complete model of the significant independent predictors explained 18% of the variance in the bed Der p 1 levels, in which 11% was explained by age and base structure of the house and the age of the mattress. The adjusted Der p 1 levels in old houses, houses with stumps and with an old mattress were 1.5-fold compared with the reference categories.

Floor Der p 1 levels

We observed a significant association between season and floor Der p 1 levels ($P < 0.05$), where Der p 1 levels were lower during winter and spring compared with the other

two seasons. However, indoor relative humidity or temperature did not have any significant influence on floor Der p 1 levels.

Centrally heated houses had 1.4-fold higher floor Der p 1 levels than other houses (Table 1). We examined the confounding effect of external ventilation on the association between central heating and Der p 1 levels. Centrally heated houses were found to be less ventilated as assessed by airing practices such as windows not being open at the time of the visit and airing of the bedroom less than once a week. Poorer ventilation as indicated by these proxy measures was also found to increase the floor Der p 1 levels, though this association was not statistically significant. However, central heating remained a significant predictor of floor Der p 1 levels, even after accounting for the variability in ventilation practices. Almost all (92%) centrally heated houses had ducted gas heating, thus it was not possible to examine the effects of different types of central heating.

Floor Der p 1 levels were significantly higher in bedrooms with drapes or heavy curtains compared with the houses without these window dressings (Table 1). Houses with venetian blinds had significantly lower levels of Der p 1 (Table 1) compared with those without. Only the association between heavy drapes and high Der p 1 levels remained statistically significant when the variation in other window dressings was considered.

An extractor fan over the stove and free standing homes were associated with a 1.5-fold increase in floor Der p 1 levels compared with the reference category (Table 1), but these associations were found to be due to confounding factors. The effect of the extractor fan was found to be due to its significant association with fitted carpets. Houses with fitted carpets had 3.7-fold higher floor Der p 1 levels compared with houses without fitted carpets (Table 1).

The effect of a free standing home was due to its association with the age of the house as described earlier.

Weather board (timber) walls and the age of the house were not found to have a statistically significant influence on floor Der p 1 levels in the univariate analysis, but emerged as significant in the multivariate analysis. The weather board walls were negatively associated with fitted carpets, which by themselves predicted higher floor Der p 1 levels. The weather board walls were identified as an independent predictor of higher floor Der p 1 levels once the variation in fitted carpets was controlled. The association between the age of the house and floor Der p 1 levels was also found to be negatively confounded by central heating. The presence of central heating was significantly associated with higher floor Der p 1 levels as well as with newer houses. Once the variation in the presence of central heating was accounted for, the age of the house became a significant predictor of floor Der p 1 levels.

The season, age of the house, wall type, heating, floor coverings and dampness in the bedroom were independent predictors of floor Der p 1 levels at $P < 0.05$ (Fig. 3). Houses built before 1980, those with timber walls, damp patches observed by the resident or central heating had higher floor Der p 1 levels. Higher floor Der p 1 levels were found if there were fitted carpets, if the carpets were more than one year old or of woollen fibre. Twenty percent of the variance in the floor Der p 1 levels was explained by these independent predictors and 10% was explained by fitted carpets alone. The adjusted Der p 1 levels of carpeted floors were about fourfold higher than uncarpeted floors.

We also examined the significance of the identified predictors while controlling for the sampling technique (i.e. standard vs extended) and the results were similar.

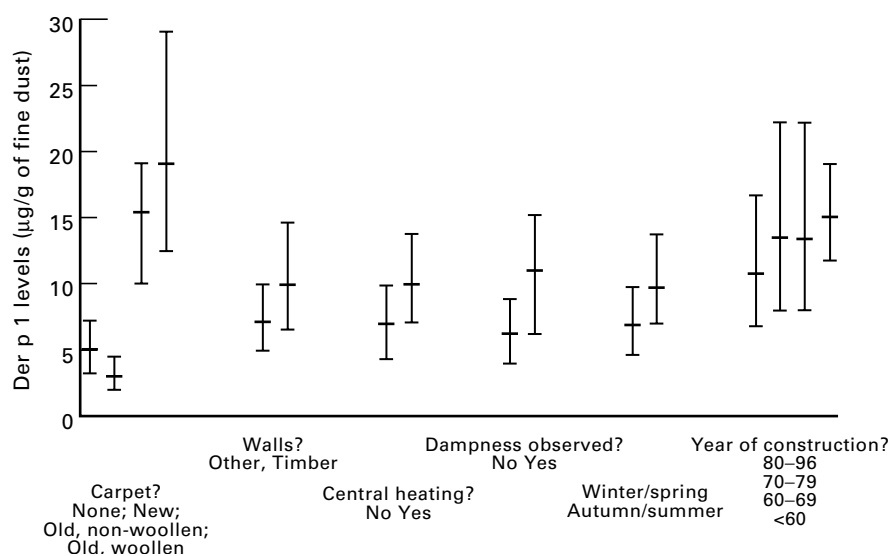


Fig. 3. Predictors of floor Der p 1 Levels. Geometric means & 95% CI adjusted for other predictors and relative humidity.

Discussion

We identified relative humidity, season, type of construction and the age of the house, floor coverings, age of the mattress, observed dampness and observed mould as statistically significant predictors of Der p 1 levels in the bedrooms of Melbourne homes.

We observed very high levels of bed and floor Der p 1 levels in this sample of houses, as has been recently described by others [5]. Almost all participants were exposed to Der p 1 levels above the proposed level for sensitization [24]. Three quarters of the sample were exposed to levels above the proposed threshold for inducing of attacks of asthma [24]. These findings highlight the clinical significance of house dust mite allergen levels in homes in Australia and the importance of further investigating the determinants of high indoor Der p 1 levels.

Our observation of higher Der p 1 levels in the bed than the floor has been described previously [10]. This may reflect increased skin shedding or different cleaning practices in the bed compared with the floor. The predictors of floor and bed Der p 1 levels were found to be similar, but not exactly the same. The relatively modest correlation observed between floor and bed Der p 1 levels highlights this observation.

The findings related to relative humidity, temperature and season should be interpreted while taking limitations such as the short duration of the measurement and the cross-sectional nature of the data into account.

High indoor relative humidity was found to increase bed Der p 1 levels, but not floor Der p 1 levels. However, floor Der p 1 levels were associated with observed bedroom dampness which has been recognized as an indicator of high indoor relative humidity as well as high Der p 1 levels [9,25,26]. Season was found to influence floor Der p 1 levels but not bed Der p 1 levels. Wickens *et al.* reported similar findings on the associations between season, relative humidity and Der p 1 levels in the bed and floor [12].

Relative humidity of $\geq 45\%$ has been shown to increase the risk of Der p 1 levels markedly [11] and the RH in 95% of the bedrooms in our sample was above this threshold. This may explain the lack of association between the indoor humidity and floor Der p 1 levels. The observed importance of relative humidity in beds may be due to higher bed temperatures lowering the humidity and making the humidity a factor which limits mite growth in the bed environment [12]. The lack of seasonal variation in bed Der p 1 levels has been attributed to the more stable and insulated micro environment compared with floors [12].

The lack of any association between temperature and Der p 1 levels in this study may be partly explained by the small range in indoor temperatures. The effect of temperature on house dust mite survival is known to occur mainly with

more extreme values [27]. However, when relative humidity was below 65%, a trend in the reduction of Der p 1 levels with increasing temperature was observed, although this was not statistically significant at 5% level. It has been suggested that high temperature influences the critical relative humidity which mites can tolerate [27,28]. On the other hand we observed high Der p 1 levels in houses with central heating, as observed by others [11] which is inconsistent with this hypothesis. Central heating has been suggested to increase Der p 1 levels due to the absence of external ventilation, which itself is associated with high Der p 1 levels [9,10] and a risk factor for HDM sensitization [29]. This was confirmed by our results which showed that the centrally heated houses were not only warmer, but also less ventilated. However, adjustment for ventilation did not change the association of centrally heated houses with high Der p 1 levels. The possibility of random misclassification of ventilation should be considered in interpreting these results. It should also be noted that the information we collected was on the presence of a central heating system and not directly on the usage of the system. Hence the presence of central heating may be a proxy measure of the ventilation of the house rather than the temperature. Hart and Whitehead found that the 'use of central heating' was associated with fewer mites in the mattress [28].

Combining available knowledge and the present findings, we suggest that keeping the environment warm at lower relative humidity may reduce the Der p 1 levels through retarding growth of HDM. The high indoor relative humidities observed in all the houses together with the association between relative humidity and Der p 1 levels indicate the importance of formulating control measures to reduce indoor relative humidity. However, measures such as increased ventilation, which have shown to be effective in Scandinavian countries, may not be as relevant to Melbourne because of the higher outdoor humidity [30].

Wooden houses, particularly houses built either with weather board walls or on stumps with wooden flooring, seemed to harbour higher Der p 1 levels than others. Munir *et al.* [9] observed higher mite allergen levels in houses without a basement and attributed this to the direct contact of flooring with moisture. This argument may also be applicable to wooden flooring. Stumps with wooden flooring compared with concrete slabs may expose the indoor environment directly to underground moisture. These findings have major implications for home construction.

Higher Der p 1 levels have been found in free standing homes and in bedrooms on the ground floor by the others [13,31]. Our data suggest that the effect of the type of house and level of bedroom arise as a result of the confounding effects of the age of the house. Older houses had higher bed and floor Der p 1 levels after accounting for relative humidity, construction type, age of the carpet and mattress

which is in keeping with the present knowledge [12–15,28,32]. Lower Der p 1 levels in newer homes has been attributed to the warmer and drier environment as a result of more efficient insulation and use of central heating [28]. However, we observed higher Der p 1 levels in centrally heated houses probably due to them being less ventilated according to our data. Hence, this needs to be examined in a study that is specifically designed to identify the relevant components in a modern house that might help to reduce the indoor Der p 1 levels.

The age of the mattress and fitted carpets accounted for a high proportion of variability in Der p 1 levels. Fitted carpets had the highest magnitude of the effect (fourfold increase compared with the reference category) among all the variables examined. These highlight the importance of encasement of mattresses and the exclusion of carpets from the environment.

The association that we observed between higher Der p 1 levels and woollen carpets has been described previously [16]. We also found higher Der p 1 levels in wool-filled quilts compared with synthetic or feather filling, though this was not statistically significant. Hill *et al.* [5] observed higher Der p 1 levels on the surface of woollen mattress covers compared with mattresses with other types of covers or no covers. Wool may create a microenvironment which favours the growth of HDM.

The number of occupants have been found to influence the Der p 1 levels in a few recent studies [12,14]. Although the associations observed in this study are unlikely to be confounded by the number of occupants in the home, we did not have data to examine this.

Some studies describe the problem of dust not being sufficient for the assay in some of the samples collected using the standard protocol i.e. vacuuming over 2 m² for 2 min [5,11]. These samples were either excluded from the analysis [11] or half of the minimum detection level in the assay was arbitrarily assigned as the Der p 1 level [5]. Exclusion of some samples is likely to cause selection bias. Assignment of an artificially low value will misclassify Der p 1 levels as the reason for the inability to identify the allergen level is due to the low levels of dust and not necessarily the Der p 1 levels themselves. We modified the standard protocol [20] to be able to identify allergen levels from homes which otherwise would have had to be assigned an arbitrary value and feel this is a preferable strategy.

In conclusion, this study has emphasized the importance of residential characteristics in reducing the HDM allergen levels and highlighted the need for further research in this field. From a public health perspective, we would encourage construction of homes without carpets, wooden floors on stumps or weather board walls. We would also encourage the removal of old woollen carpets and visible mould,

encasement of mattresses and control of dampness and humidity.

Acknowledgements

We would like to thank the Victorian Health Promotion Foundation and Department of Human Services for funding this study. We acknowledge the assistance received in data collection from Tina Colgan and John Elliot.

References

- 1 Sporik R, Holgate ST, Platts-Mills TA, Cogswell JJ. Exposure to house-dust mite allergen (Der, p I) and the development of asthma in childhood. A prospective study. *N Engl J Med* 1990; 323:502–7.
- 2 Peat JK, Tovey E, Toelle BG et al. House dust mite allergens. A major risk factor for childhood asthma in Australia. *Am J Respir Crit Care Med* 1996; 153:141–6.
- 3 Ehnert B, Lau-Schadendorf S, Weber A, Buettner P, Schou C, Wahn U. Reducing domestic exposure to house dust mite allergen reduces bronchial hyperreactivity in sensitive children with asthma. *J Allergy Clin Immunol* 1992; 90:135–8.
- 4 Platts-Mills TAE, Michell EB, Nock P, Tovey ER, Mosoro H, Wilkins SF. Reduction of bronchial hyperreactivity during prolonged allergen avoidance. *Lancet* 1982; 2:675–8.
- 5 Hill DJ, Thompson PJ, Stewart GA, Carlin JB, Nolan TM, Kemp AS et al. The Melbourne house dust mite study: eliminating house dust mites in the domestic environment. *J Allergy Clin Immunol* 1997; 99:323–9.
- 6 ECRHS. Variations in the prevalence of respiratory symptoms, self-reported asthma attacks, and use of asthma medication in the European Community Respiratory Health Survey (ECRHS). *Eur Respir J* 1996; 9:687–95.
- 7 Peat JK, van den Berg RH, Green WF, Mellis CM, Leeder SR, Woolcock AJ. Changing prevalence of asthma in Australian children. *BMJ* 1994; 308:1591–6.
- 8 Hopper JL, Jenkins MA, Carlin JB, Giles GG. Increase in the self-reported prevalence of asthma and hay fever in adults over the last generation: a matched parent-offspring study. *Aust J Public Health* 1995; 19:120–4.
- 9 Munir AK, Bjorksten B, Einarsson R et al. Mite allergens in relation to home conditions and sensitization of asthmatic children from three climatic regions. *Allergy* 1995; 50:55–64.
- 10 Sundell J, Wickman M, Pershagen G, Nordvall SL. Ventilation in homes infested by house-dust mites. *Allergy* 1995; 50:106–12.
- 11 Dornelas de Andrade A, Birnbaum J et al. Housing and house-dust mites. *Allergy* 1995; 50:142–6.
- 12 Wickens K, Siebers R, Ellis I et al. Determinants of house dust mite allergen in homes in Wellington, New Zealand. *Clin Exp Allergy* 1997; 27:1077–85.
- 13 Kuehr J, Frischer T, Karmaus W et al. Natural Ventilation in mite antigen density in house dust and relationship to residential factors. *Clin Exp Allergy* 1994; 24:229–37.
- 14 Strien RTV, Verhoeff AP, Brunekreef B, Wijnen JHV. Mite antigen in house dust: relationship with different housing

- characteristics in the Netherlands. *Clin Exp Allergy* 1994; 24:843–53.
- 15 Chan Yeung M, Becker A, Lam J et al. House dust mite allergen levels in two cities in Canada: effects of season, humidity, city and home characteristics. *Clin Exp Allergy* 1995; 25:240–6.
- 16 Price JA, Pollock I, Little SA, Longbottom JL, Warner JO. Measurement of airborne mite antigen in homes of asthmatic children. *Lancet* 1990; 336:895–7.
- 17 Kemp TJ, Siebers RW, Fishwick D, O'Grady GB, Fitzharris P, Crane J. House dust mite allergen in pillows. *BMJ* 1996; 313:916.
- 18 Abramson MJ, Kutin J, Raven J, Lanigan A, Czarny D, Walters EH. Risk factors for asthma among young adults in Melbourne. *Respirology* 1996; 1:291–7.
- 19 Burney PG, Luczynska C, Chinn S, Jarvis D. The European Community Respiratory Health Survey. *Eur Respir J* 1994; 7:954–60.
- 20 Platts-Mills TAE, De Weck AL. Dust mite allergens and asthma A worldwide problem. *J Allergy Clin Immunol* 1989; 83:416–27.
- 21 Chapman MD, Heymann PW, Wilkins SR, Brown MJ, Platts-Mills TA. Monoclonal immunoassays for major dust mite (*Dermatophagoides*) allergens, Der p. I and Der f I, and quantitative analysis of the allergen content of mite and house dust extracts. *J Allergy Clin Immunol* 1987; 80:184–94.
- 22 Luczynska CM, Arruda LK, Platts-Mills TAE, Lopez M, Chapman MD. A two site monoclonal antibody ELISA for quantification of the major *Dermatophagoides* spp. allergens, Der p 1 and Der f 1. *J Immunol Methods* 1989; 118:227–35.
- 23 SAS. Stat User's guide. Cary, NC, USA. SAS institute Inc. 1988.
- 24 Platts-Mills TAE, Thomas WR, Alberse RC, Vervloet D, Chapman MD. Dust mite allergens and asthma: report of the second international work-shop. *J Allergy Clin Immunol* 1992; 89:1046–60.
- 25 Custovic A, Taggart SC, Kennaugh JH, Woodcock A. Portable dehumidifiers in the control of house dust mites and mite allergens. *Clin Exp Allergy* 1995; 25:312–6.
- 26 Wickman M, Emenius G, Egmar AC, Axelsson G, Pershagen G. Reduced mite allergen levels in dwellings with mechanical exhaust and supply ventilation. *Clin Exp Allergy* 1994; 24:109–14.
- 27 Arlian LG, Bernstein IL, Gallagher JS. The prevalence of house dust mites, *Dermatophagoides* spp, and associated environmental conditions in homes in Ohio. *J Allergy Clin Immunol* 1982; 69:527–32.
- 28 Hart BJ, Whitehead L. Ecology of house dust mites in Oxfordshire. *Clin Exp Allergy* 1990; 20:203–9.
- 29 Wickman M, Nordvall SL, Pershagen G, Sundell J, Schwartz B. House dust mite sensitization in children and residential characteristics in a temperate region. *J Allergy Clin Immunol* 1991; 88:89–95.
- 30 Colloff MJ. Dust mite control and mechanical ventilation: when the climate is right (ed.) *Clin Exp Allergy* 1994; 24: 94–6.
- 31 Wickman M, Nordvall SL, Pershagen G, Korsgaard J, Johansen N. Sensitization to domestic mites in a cold temperate region. *Am Rev Respir Dis* 1993; 148:58–62.
- 32 Korsgaard J. Mite Asthma and Residency. *Am Rev Respir Dis* 1983; 128:231–5.