

Indoor factors associated with concentrations of house dust mite allergen, Der p 1, in a random sample of houses in Norwich, UK

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Summary

Background Studies of house dust mite allergen concentrations suggest large variations both within and between homes. It is likely that different household characteristics influence allergen levels in different locations within the house.

Objectives To investigate household characteristics associated with higher concentrations of house dust mite allergen in a random sample of houses.

Methods Information on indoor environment was obtained from 158 adults aged 20–44. Dust samples were collected from their living room floor, bedroom floor and mattress. Concentrations of Der p 1, the major allergen from the house dust mite *Dermatophagoides pteronyssinus*, were measured by monoclonal antibody immunoassay. Associations between mite allergen concentrations and household characteristics were examined using censored-normal regression models. Factors that were related to Der p 1 ($P \leq 0.2$) in univariate analyses were included in multivariable regression models.

Results Der p 1 was not detected in any location in 10 (6.3%) houses. Geometric mean concentrations of Der p 1 were 1.9 $\mu\text{g/g}$ in living room floor dust, 1.7 $\mu\text{g/g}$ in bedroom floor dust and 2.0 $\mu\text{g/g}$ in mattress dust. Approximately 25% of living room floor and mattress, and over 30% of bedroom floor samples had Der p 1 concentrations greater than 10 $\mu\text{g/g}$. Household characteristics associated with Der p 1 concentrations in both living room and bedroom were floor level, extractor fan in the kitchen, and age of carpet. Living room Der p 1 concentrations were also associated with gas oven/hob, window condensation, open fires, vacuum cleaner type, smokers in the house and age of house. Bedroom Der p 1 concentrations were also associated with use of blankets and wash temperature of bedding. Mattress Der p 1 concentrations were associated with window condensation, concrete bedroom floor and age of mattress.

Conclusion Different household characteristics were associated with high Der p 1 concentrations in different parts of the house. These findings are relevant to design of allergen avoidance regimes or formulation of policy recommendations for reduction of disease associated with allergen exposure.

Keywords: *Dermatophagoides pteronyssinus*, Der p 1, risk factors, household characteristics

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Introduction

House dust mites have been recognized as the main source of allergens in dust associated with allergic disease for a number of years [1]. In the UK the most predominant mite is

Dermatophagoides pteronyssinus [2,3]. Skin test results from a recent survey in East Anglia (UK) showed that $\approx 30\%$ of adults were sensitized to *Dermatophagoides pteronyssinus* [4]. There is evidence that mite allergen exposure is necessary for sensitization [5] and that mite sensitization is a risk factor for asthma [6,7]. There is also evidence for a relationship between mite exposure and asthma symptoms in sensitized individuals [8], and that allergen avoidance can lead to a decrease in symptomatic asthma in sensitized individuals [9,10]. It is therefore important to understand which environmental factors in homes are risk factors for high allergen exposure, and thus which of these factors can be modified in order to reduce morbidity in those individuals with mite-allergic asthma.

Since the development of quantitative tests for the major allergen from *Dermatophagoides pteronyssinus*, Der p 1 [11,12], a number of studies have looked at environmental and residential characteristics that may be risk factors for house dust mite allergen. Studies in Sweden [13,14], Germany [15], France [16] and New Zealand [17] all identify different risk factors associated with high levels of indoor allergens. There is substantial variation in the distribution of house dust mites between geographical areas [18], and it is likely that risk factors for high allergen concentrations will differ between regions and between locations in the home [19]. Household characteristics associated with high allergen levels in the UK remain to be identified. The aim of this study was to describe the occurrence of house dust mite allergen and household characteristics that are risk factors for high mite allergen concentrations in a group of houses in Norwich, UK.

Materials and methods

Selection of subjects

Three hundred adults, aged 20–44 years old, living in different households in central Norwich (postcodes NR1–NR6) were selected at random from the Family Health Services Authority register and were invited to take part in a study of indoor allergen exposure. A total of 158 (52.7%) agreed to participate. Of the non-responders, 26 were found to be wrong addresses and to have moved (adjusted response rate 57.7%).

Assessment of exposure factors and Der p 1 concentrations

A questionnaire on household characteristics thought to be associated with high concentrations of indoor allergens was designed. This included questions from the European Community Respiratory Health Survey questionnaire [20] and from a Swedish study of known and suspected risk factors for high levels of Der p 1 [13]. The questionnaire

comprised 14 questions on household factors that are likely to affect humidity and/or temperature (e.g. floor level, window condensation, visible damp or mould), five questions on ventilation (e.g. presence of double glazing, extractor fans, airing habits), six questions on factors affecting dust levels (e.g. type of vacuum cleaner, frequency of vacuuming, age of carpet and mattress). In addition there were questions on type, age and construction of the house, proximity to natural water, and whether there were smokers living in the house.

The houses were visited over the course of 13 months by one fieldworker who administered the questionnaire. Dust samples were taken in a standardized manner, using a Hoover Portapower vacuum cleaner (850 W) and an ALK sampling device (ALK Laboratories, Horsholm, Denmark) [21], sampling 1 m^2 of the living room floor, bedroom floor and mattress for 2 min using a zig-zag pattern as described by Colloff [2]. The living room floor sample was taken from the central area of the room and the bedroom floor sample from the part of the floor next to the bed. Mattress samples were taken from the layer of bedding beneath the bottom sheet. The dust samples were weighed, passed through a $300\text{ }\mu\text{m}$ sieve and 5% extracts prepared in borate buffered saline, pH 8, which were stored at -20°C until analysed. Der p 1 concentrations were measured using a two-site monoclonal antibody enzyme-linked immunosorbent assay (ELISA) [11]. Results were expressed in $\mu\text{g/g}$ Der p 1 and the detection limit of the assay was $0.1\text{ }\mu\text{g/g}$. Because there is considerable potential variability in the sampling and assay of allergens [22], the questionnaires and dust sampling were carried out by the same fieldworker throughout the study, and all the ELISA of dust samples were carried out by the same technician.

Statistical analyses

Data were analysed using the statistical package Stata (Stata Corporation, Texas, USA). Each household characteristic was categorized as relevant to one or more of the living room, bedroom or mattress and its association with Der p 1 concentrations in the relevant location was examined. All bedroom and mattress characteristics were considered relevant to both bedroom floor and mattress. To present the results, household characteristics have been grouped into those affecting humidity and/or temperature, ventilation, dust reservoir levels and variables not fitting into these categories.

As the distribution of Der p 1 was positively skewed, censored-normal regression analyses were carried out using log Der p 1 [23]. Initial (univariate) analyses examined the proportion of households in which Der p 1 was detected, geometric mean Der p 1 (where detected) and difference in mean Der p 1, using a method which allows for

left-censoring where the concentration was below the detection level of the assay. Left-censoring allows information on values below a certain level that cannot be measured to be incorporated, on the assumption that the whole distribution (including the left-censored observations) is normal. For those variables where univariate analyses revealed a possible association ($P \leq 0.2$), joint effects were examined using a multiple regression model to control for the effects of the other such characteristics, again allowing for left-censoring. In this way, the multivariable model was used to estimate the association of each household characteristic with mite allergen concentrations, controlling for all other characteristics with (univariate) evidence of an association which could confound the outcome with another exposure of interest without necessarily having a significant (i.e. $P < 0.05$) association.

Results

Geometric mean Der p 1 concentrations and ranges are shown in Table 1. Approximately half of the houses tested had Der p 1 concentrations greater than $2 \mu\text{g/g}$ in at least one location. Ten houses (6.3%) had undetectable Der p 1 in any location tested, and 27.2% of living room, 32.5% of bedroom and 26.3% of mattress dust samples had more than $10 \mu\text{g/g}$ Der p 1. Although geometric mean Der p 1 was similar in three locations tested, there was wide variation between houses, particularly in mattress dust. The correlations between log concentrations in the different locations were 0.42 ($P < 0.0001$) between the bedroom floor and mattress, 0.34 ($P = 0.0002$) between the living room and bedroom floors and 0.17 ($P = 0.07$) between the living room floor and mattress. There was no seasonal variation observed in any of the locations tested, as there was no difference in the mean Der p 1 concentration measured in samples collected during the months corresponding to the four seasons.

Der p 1 in living room floor

Household characteristics for which there was evidence of an association with living room floor Der p 1 concentrations ($P \leq 0.1$), after controlling for other factors, are shown in Table 2. Living rooms above the ground floor or living rooms in houses where the bedroom is above the ground floor had greatly reduced concentrations of Der p 1 in floor dust. Living rooms in houses where gas was used for cooking had two and a half times more Der p 1 after controlling for the effects of other characteristics. An open fireplace in the living room was considered to be a factor that affected ventilation as open fires were not a primary source of heating in any of the houses, and Der p 1 concentrations in the living room were found to be reduced by 85% when there was an open fireplace. Having an extractor fan in the kitchen was also associated with lower Der p 1 in the living room. There was twice as much Der p 1 in living rooms which had condensation on windows anywhere in the house, and three times as much when the condensation was in the living room itself. Of factors likely to affect dust levels, having an old-style vacuum cleaner (with a soft bag) and having a carpet more than 1 year old were associated with higher concentrations of Der p 1. There was an inverse association between living room Der p 1 concentrations and the number of smokers in the house and there were lower concentrations of Der p 1 in the living room in newer houses.

Der p 1 in bedroom floor

Factors associated with Der p 1 in bedroom floor dust are shown in Table 3. Bedrooms that were not on the ground floor or in a basement had greatly reduced Der p 1 concentrations. Among factors affecting ventilation there was some evidence that having an extractor fan in the kitchen was associated with lower concentrations of Der p 1 on the

Table 1. Concentrations and distribution of Der p 1 in different locations in 158 houses

	Living room floor	Bedroom floor	Mattress
Geometric Mean Der p 1 ($\mu\text{g/g}$, 95% C.I.)	1.9 (1.3–2.7)	1.7 (1.1–2.5)	2.0 (1.4–2.9)
Range ($\mu\text{g/g}$)	<0.1–259.0	<0.1–357.7	<0.1–819.8
Houses (n, %) with Der p 1 ($\mu\text{g/g}$):			
<0.1	23/158 (14.6)	25/154 (16.2)	24/156 (15.4)
0.1–1.9	54/158 (34.2)	57/154 (37.0)	51/156 (32.7)
2.0–9.9	38/158 (24.0)	22/154 (14.3)	40/156 (25.6)
>10.0	43/158 (27.2)	50/154 (32.5)	41/156 (26.3)

Table 2. Household characteristics associated with Der p 1 in the living room

Univariate analyses					Controlling for all characteristics where $P \leq 0.2^*$	
Variable	Categories	n	Geometric mean (GM) Der p 1 (95% CI) ($\mu\text{g/g}$)	P	Ratio of GM Der p 1 to baseline (95% CI)	P
<i>Factors affecting humidity and/or temperature:</i>						
Floor level of living room	Basement/ground	146	3.7 (2.7, 5.2)	<0.001	1.00	0.002
	Upstairs	12	0.7 (0.2, 2.8)		0.03 (0.00, 0.26)	
Floor level of bedroom	Ground floor	20	7.2 (3.0, 17.4)	0.006	1.00	0.02
	Upstairs	136	3.0 (2.1, 4.3)		0.27 (0.09, 0.81)	
Gas oven or hob	No	54	3.0 (1.6, 5.4)	0.13	1.00	0.02
	Yes	104	3.7 (2.5, 5.5)		2.52 (1.14, 5.56)	
Window condensation	No	33	2.8 (1.4, 5.7)	0.02	1.00	0.07
	Yes, elsewhere	72	3.4 (2.2, 5.4)		2.03 (0.89, 4.66)	
	Yes, in living room	30	4.5 (2.3, 8.7)		3.33 (1.17, 9.45)	
<i>Factors affecting ventilation:</i>						
Open fire in living room	No	136	4.0 (2.8, 5.7)	0.03	1.00	0.006
	Yes	21	1.1 (0.5, 2.3)		0.15 (0.04, 0.56)	
Extractor fan in kitchen	No or never used	109	3.9 (2.6, 5.8)	0.20	1.00	0.04
	Vented inside	24	2.5 (1.2, 5.4)		0.65 (0.26, 1.67)	
	Vented outside	25	3.0 (1.1, 7.7)		0.27 (0.10, 0.75)	
<i>Factors affecting dust reservoirs:</i>						
Type of vacuum cleaner	Old (soft bag)	14	6.3 (2.5, 15.6)	0.005	1.00	0.002
	New (cylinder)	129	3.3 (2.3, 4.8)		0.37 (0.11, 1.26)	
	None/unspecified	11	2.0 (0.4, 9.3)		0.04 (0.01, 0.24)	
Age of living room carpet	No carpet	7	1.0 (0.4, 2.5)	0.02	1.00	0.05
	Less than 1 year	14	0.8 (0.3, 1.7)		1.82 (0.41, 8.12)	
	More than 1 year	131	5.1 (3.6, 7.3)		3.66 (1.21, 11.10)	
<i>Other factors:</i>						
Smokers in house	None	94	5.0 (3.3, 7.4)	0.007	1.00	0.003
	One	37	1.9 (0.9, 4.0)		0.42 (0.18, 0.97)	
	Two or more	21	1.5 (0.6, 3.7)		0.18 (0.06, 0.52)	
Year of construction	Pre-1960	110	3.5 (2.4, 5.2)	0.06	1.00	0.04
	1961 to 1980	30	3.8 (1.8, 8.3)		0.66 (0.26, 1.69)	
	Post-1980	17	2.3 (0.7, 7.5)		0.19 (0.05, 0.66)	

* Factors included in analyses but with $P > 0.1$ after controlling for other characteristics in the table: type of house, double glazing, use of heaters other than central heating, extractor fan in bathroom, frequency of airing the living room, frequency of vacuuming the living room floor. Factors not included in analyses ($P > 0.2$ in univariate analysis): having a basement or cellar, concrete floor, central heating, gas boiler, damp patches, mould or mildew, drying clothes indoors.

bedroom floor if the fan was vented to the outside but higher concentrations if vented inside. The use of blankets on the bed and a bedroom carpet more than 1 year old were both associated with higher Der p 1 concentrations. There was also some evidence that washing bedding at temperatures above 40°C was associated with reduced Der p 1 in bedroom floor dust.

Der p 1 in the mattress

Table 4 shows the household characteristics associated with Der p 1 concentrations in the mattress. The presence of condensation on the bedroom window and having a mattress more than 1 year old were associated with an increase in Der p 1 concentrations of three and five times, respectively.

Table 3. Household characteristics associated with Der p 1 in the bedroom

			Univariate analyses		Controlling for all characteristics where $P \leq 0.2^*$	
Variable	Categories	n	Geometric mean (GM) Der p 1 (95% CI) ($\mu\text{g/g}$)	P	Ratio of GM Der p 1 to baseline (95% CI)	P
<i>Factors affecting humidity and/or temperature:</i>						
Floor level of bedroom	Basement/ground	20	19.0 (12.3, 29.3)	<0.001	1.00	<0.001
	Upstairs	133	2.5 (1.7, 3.7)		0.04 (0.01, 0.21)	
<i>Factors affecting ventilation:</i>						
Extractor fan in kitchen	Never used	106	3.6 (2.3, 5.5)	0.05	1.00	0.05
	Vented inside	24	3.3 (1.4, 7.9)		2.36 (0.77, 7.20)	
	Vented outside	24	2.4 (0.8, 6.7)		0.40 (0.12, 1.30)	
<i>Factors affecting dust reservoirs:</i>						
Use of blankets	No blankets	94	2.3 (1.4, 3.7)	0.005	1.00	0.01
	Yes, cleaned	53	6.0 (3.3, 10.6)		3.92 (1.63, 9.45)	
	Yes, not cleaned	7	4.0 (1.1, 13.7)		0.91 (0.13, 6.47)	
Age of bedroom carpet	No carpet	7	0.7 (0.2, 2.5)	0.10	1.00	0.01
	Less than 1 year	14	2.1 (1.0, 4.4)		0.64 (0.06, 6.51)	
	More than 1 year	131	3.9 (2.7, 5.9)		4.75 (0.73, 30.94)	
<i>Other factors:</i>						
Wash temperature of bedding	Less than 40°C	37	3.1 (1.7, 5.8)	0.07	1.00	0.05
	41°C–60°C	84	3.0 (1.7, 5.3)		0.41 (0.15, 1.06)	
	More than 60°C	15	3.5 (1.3, 9.2)		1.09 (0.26, 4.55)	
	Unknown	16	4.4 (1.5, 13.1)		2.19 (0.49, 9.70)	

* Factors included in analyses but with $P > 0.1$ after controlling for other characteristics in the table: having a concrete floor, window condensation, damp patches, mould or mildew, type of vacuum cleaner, central heating, drying clothes indoors, use of heaters other than central heating, frequency of vacuuming the bedroom. Factors not included in analyses ($P > 0.2$ in univariate analyses): type of house, year of construction, having a basement or cellar, double glazing, gas oven or hob, gas boiler, open fire in living room, extractor fan in bathroom, smokers in house, frequency of airing the bedroom.

Having a concrete floor in the bedroom was also a risk factor for increased Der p 1 in the mattress which was independent of which floor the bedroom was on.

Household characteristics associated with high Der p 1 concentrations in univariate analyses but not multivariate analyses

For a number of household factors apparent associations in univariate analyses were reduced or abolished after controlling for the effects of the other household characteristics. These are listed in the footnotes to Tables 2, 3 and 4.

Factors not influencing Der p 1 concentrations in any analysis

Table 5 summarizes the household characteristics tested that were found to have no association with Der p 1

concentrations in any location of the house. These include factors thought to be associated with increased damp in the home, such as living near a lake or river and having had leaks or floods in the house. In addition, vacuuming the mattress did not affect Der p 1 concentrations in the mattress.

Discussion

A concentration of $2 \mu\text{g/g}$ Der p 1 has been proposed as a risk factor for sensitization to house dust mites and allergic symptoms, and $10 \mu\text{g/g}$ Der p 1 as a risk factor for acute symptoms, for example an asthma attack, in sensitized individuals [24]. In this study, approximately half of the houses had more than $2 \mu\text{g/g}$ Der p 1, and a quarter of the houses had more than $10 \mu\text{g/g}$ Der p 1 in one of the locations tested.

Table 4. Household characteristics associated with Der p 1 in the mattress

			Univariate analyses		Controlling for all characteristics where $P \leq 0.2^*$	
Variable	Categories	n	Geometric mean (GM) Der p 1 (95% CI) ($\mu\text{g/g}$)	P	Ratio of GM Der p 1 to baseline (95% CI)	P
<i>Factors affecting humidity and/or temperature:</i>						
Window condensation	No	45	3.4 (1.9, 5.9)	0.10	1.00	0.04
	Yes, elsewhere	38	3.1 (1.6, 6.2)		0.97 (0.24, 2.59)	
	Yes, in bedroom	73	4.7 (2.8, 7.8)		2.82 (0.98, 8.09)	
Concrete floor	No	110	3.5 (2.4, 5.0)	0.007	1.00	0.09
	Yes, in bedroom	20	7.4 (2.9, 18.8)		5.76 (0.77, 43.10)	
<i>Factors affecting dust reservoirs:</i>						
Age of mattress	Less than 1 year	18	1.0 (0.5, 2.3)	0.05	1.00	0.01
	More than 1 year	136	4.7 (3.3, 6.7)		5.08 (1.47, 17.54)	

* Factors included in the analyses but with $P > 0.1$ after controlling for other characteristics in the table: mould or mildew, bedroom on ground floor, use of heaters other than central heating, use of blankets, central heating, size of bed, damp patches, use of electric blankets, gas boiler, type of vacuum cleaner, having a basement or cellar. Factors not included in analyses ($P > 0.2$ in univariate analyses): type of house, year of construction, double glazing, gas oven or hob, extractor fan in kitchen, drying clothes indoors, open fire in living room, extractor fan in bathroom, smokers in house, age of bedroom carpet, frequency of airing the bedroom, frequency of vacuuming the bedroom floor, wash temperature of bedding.

We have reported Der p 1 levels in $\mu\text{g/g}$ as allergen concentration is independent of the sampling technique (power of the vacuum cleaner, area and time of sampling, losses occurring during extraction of dust) and should not be affected by domestic activities such as time since the last vacuum cleaning. An alternative would be to report $\mu\text{g/m}^2$ (i.e. amounts rather than concentrations), however, there is a good correlation between the two measures [25].

Our analyses suggest that certain household characteristics are strongly associated with Der p 1 concentrations

and that the different characteristics are associated with concentrations in different parts of the house.

Temperature and humidity

Humidity and temperature have been shown to affect house dust mite populations in homes [26–28], as has the presence of visible damp [15]. As with a number of household characteristics, temperature and humidity are linked and it is not clear which is more important in influencing dust mite

Table 5. Household characteristics not associated with Der p 1

In living room, bedroom or mattress	In bedroom or mattress*
Living within 500 m of a lake or river	Frequency of vacuuming the mattress
Having had leaks or floods	Time since the mattress last vacuumed
Having a tumble drier	Type of bed (open or box-spring)
Airing the bathroom	Having a duvet
Closing the kitchen door while cooking	Leaving the bedroom unheated in winter
Having rugs	
Time since the last vacuum cleaning	

* not tested in the living room

populations. Absolute humidity is difficult to measure in large numbers of houses and our analyses have therefore relied on surrogate measures.

Having a living room or a bedroom on the ground floor was strongly associated with increased Der p 1 concentrations. In a study carried out in Germany [15], ground floor rooms were found to be more humid than rooms on higher floors and also to have more mite allergen. Concrete floors also contribute to indoor humidity and were associated with higher Der p 1 concentrations in the mattress. The use of unvented or inadequately vented gas appliances is also likely to increase indoor humidity, and houses with gas ovens or hobs had twice as much house dust mite allergen in the living rooms as those with electric cookers. Window condensation in the living room was associated with increased Der p 1 concentrations on the floor, and window condensation in the bedroom was one of the household characteristics which had an influence on mattress Der p 1 concentrations in our study. Wickman *et al.* [29] also reported that window condensation was a risk factor for higher Der p 1 concentrations in the mattress.

Ventilation

Having an open fireplace in the living room was associated with decreased concentrations of Der p 1 in the living room floor. This household characteristic was categorized as a variable that affected ventilation as none of the householders reported that it was a primary source of heat as the houses were centrally heated, but that the fireplace was sometimes used in winter. We speculate that the 'chimney stack' effect on ventilation in the room may contribute to a decrease in house dust mite allergen levels, and may also explain why new houses, many of which have open fireplaces included as a fashion accessory rather than for heating purposes, also have lower concentrations of house dust mite allergen. This hypothesis could be tested by carrying out air exchange rate measurements in homes with and without open chimney stacks.

An extractor fan in the kitchen, mandatory in all new buildings in the UK, was found to be associated with lower concentrations of mite allergen in both living room and bedroom floors. The UK has a mild, wet winter climate where mites are likely to be present in every home. Colloff [30] has argued that use of mechanical ventilation to reduce mite allergen levels in such countries with high outdoor humidity is futile, but these results might suggest otherwise. However, none of the factors affecting ventilation rates in the house had an effect on mattress Der p 1. Ventilating rooms is unlikely to have much effect on mattress humidity levels unless the bedding is also aired, a practice that seems to have been largely abandoned in the west but is still common in central and eastern Europe.

Factors affecting dust reservoirs

There has been much focus of attention on the role of 'new style' vacuum cleaners with increased flow rates and improved filters [31] and our findings suggest that having a new vacuum cleaner contributes to reduced Der p 1 concentrations in the living room floor. Previous studies have suggested that carpeted floors contain more mite allergen than uncarpeted floors [32]. Our study found that having a carpet more than a year old was strongly associated with high Der p 1 concentration in floors, a finding that was also reported recently in New Zealand [17] where overall the levels of Der p 1 are much higher. Whereas the effect of indoor humidity may depend on climate or geographical region, it seems more plausible that factors affecting dust reservoirs might have the same associations with mite levels in different parts of the world.

Similarly, our finding that a mattress more than a year old was a risk factor for high mite allergen levels was consistent with the studies of Mosbech *et al.* [33] and Custovic *et al.* [34]. The observation that the more successful allergen avoidance studies included the use of mattress covers [10,35] supports the role of the mattress as an important source of mite allergen exposure.

Other household characteristics

Presence and increasing numbers of smokers in the house were strongly associated with decreased concentrations of Der p 1 in the living room. The relationship did not hold for the bedroom sites, possibly because there is less smoke in the bedroom. In contrast, Munir *et al.* [14] reported that Der p 1 levels were higher in homes of smokers in Sweden. The relationship between reservoir Der p 1 and tobacco smoke is unclear and we do not know why there were lower concentrations of Der p 1 in the houses of smokers in this study. There was no evidence, for example, that the frequency of airing the living room varied according to whether or not there were smokers in the house. Our laboratory tests (unpublished) do not suggest that nicotinic acid interferes with the ELISA in the same way that tannic acid can [36], but it is possible that nicotinic acid denatures Der p 1 in the dust samples. It is also possible that nicotine has an acaricidal effect on house dust mites by blocking nicotinic receptors [37] and/or inhibiting protein synthesis [38]. We are carrying out studies to investigate these hypotheses.

Newer houses, built after 1980, had lower concentrations of Der p 1 in the living room, possibly because in general all the furnishings and fittings were likely to be newer, or because these houses were more likely to have extractor fans in the kitchen.

The wash temperature of the bedding appeared to be related to Der p 1 concentrations in the bedroom floor,

though not the mattress. McDonald and Tovey [39] investigated the role of wash temperature in eliminating mites and reported that all mites were killed at temperatures above 55°C and that Der p 1 concentrations in bedding were reduced to below 2 µg/g. We found lowered Der p 1 concentrations when washing above 40°C, but no effect on Der p 1 when washing at higher temperatures. We have no explanation for the results relating to wash temperature but note that the numbers in some categories are small with correspondingly wide confidence intervals. However, Der p 1 is highly soluble and thus likely to be washed out at lower temperatures than would be required to kill mites.

Although many of the risk factors identified as being associated with increased mite allergen levels will be difficult to modify, removing carpets and covering mattresses may be measures which can reduce exposure to house dust mite allergen. Our study also suggests that mite allergic asthmatics should avoid having their bedrooms on the ground floor and supports the role of adequate ventilation in the kitchen as a means of reducing indoor humidity and thus house dust mite allergen levels.

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