

Household characteristics and mite allergen levels in Manchester, UK

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Summary

Background Mite allergen levels vary enormously between different homes in the same geographical area. No large scale studies of mite levels in Manchester homes has been conducted to identify factors associated with higher levels.

Objectives To quantify exposure to mite allergens and to identify characteristics associated with higher Der p 1 levels in a large sample of homes in Manchester, UK.

Methods Der p 1 was measured in dust from the living room floor, sofa, bedroom floor and mattress in 564 homes. Data on household characteristics were collected by administering a questionnaire. Univariate and multivariate analyses were performed to identify household characteristics associated with higher mite allergen levels.

Results Der p 1 levels were highest in the mattress (GM 1.19 µg/g, 95% CI 0.98–1.45, $P < 0.001$). Two-thirds of homes contained Der p 1 levels > 2 µg/g in at least one dust reservoir, and 40.3% contained Der p 1 greater than 10 µg/g. There was a large range in Der p 1 levels between homes ($> 10^3$ -fold). Damp and condensation were common findings in homes. In the multivariate analyses, factors associated with higher Der p 1 levels in more than one dust reservoir were older homes, older living room carpets, damp, condensation and mixed glazing. Older mattresses were associated with higher mite allergen levels in the mattress where the age of the mattress was recorded. Twenty-four homes contained no detectable mite allergen, six of which reported damp.

Conclusions Mite allergen levels are high enough in two of every three homes to be associated with an increase in the risk of sensitization to mite. Factors such as older homes, carpets and mattresses, damp and condensation are associated with higher mite allergen. However, mite allergen levels are occasionally unpredictably very low in homes with risk factors for high levels.

Keywords asthma, Der p 1, household characteristics, sensitization

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Introduction

Asthma has increased in prevalence over the last 40 years [1] and is a major public health problem [2, 3]. Sensitization to dust mites is a major risk factor for asthma [4] and there is a dose–response relationship between exposure to higher levels of mite allergen in the home and the development of sensitization for populations [5]. Mites live in carpets and soft furnishings where there is no liquid water. Optimal conditions for mite growth in the laboratory are 75–90% relative humidity (RH) at temperatures of 15–30 °C, but marginal mite growth occurs at lower RH and temperatures (reviewed in [6]). Previous studies in Manchester have shown that indoor RH exceeds 60% for most of the year, making indoor conditions in homes adequate to support mite growth throughout the year [7]. However, no correlation between indoor RH and Der p 1 levels was found in Manchester homes [7]. Furthermore, there was a large (10^3 – 10^4 -fold) variation in mite allergen levels among homes within the same area. This suggests that characteristics other than RH are important

determinants of mite allergen levels and therefore of mite allergen exposure of the population.

Two published studies from the UK investigating the effect of household characteristics on mite allergen levels identified various factors associated with higher mite allergen levels, but the only common factors were not having cigarette smokers in the house and older mattresses. However, the questionnaires used were quite different, as were the homes studied, one being a random selection of 158 adults [8], the other being mattresses of 643 infants [9]. Both studies identified a wide range of mite allergen levels among homes within the same geographical area.

This study quantified mite allergen levels in homes in the North-west of England and investigated the effect of various household characteristics on the mite allergen levels.

Methods

Home visits

A total of 564 homes were visited in South Manchester between September 1995 and September 1997. Homes were identified as part of screening for an allergen avoidance study, belonged to both atopic and non-atopic adults and were representative of housing in our area [10]. Each home was visited by two

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technicians/nurses to collect dust samples and administer a questionnaire. The questionnaire, a modified version of ATS-DLD-78A [11], was used to collect data on the type and age of house, type of flooring, heating, cooking fuel, windows, household income and the presence of damp, condensation and cigarette smokers in the house, amongst other factors. Part way through the study the questionnaire was modified to include data on the age of the mattress. Therefore these data are available for 319 cases only.

Dust sample collection

Dust samples were collected from the living room carpet (LF), sofa (S), bedroom carpet (BF) and mattress (M) by vacuuming a 1-m² area using a Medivac dust sampler (airflow 45 L/s; Medivac Plc, Wilmslow, Cheshire, UK) for 2 min in a standardized fashion. The sampling head was loaded with a stainless steel mesh filter, to remove particles > 300 µm diameter, allowing a sample of fine dust to be collected onto a 5-µm pore size vinyl filter (Plastok Associates Ltd, Wirral, UK). Immediately after collection, the dust sample was transferred into pre-weighed Petri dishes and coded. The filled Petri dish was weighed to calculate the mass of fine dust collected and stored at 4 °C until extraction. After each sample collection the sampling head was cleaned using 70% isopropyl alcohol.

Dust sample extraction and assay

A 100-mg aliquot of the dust was extracted by rotation with 2 mL borate-buffered saline with 0.1% Tween-20 pH 8.0, at room temperature (20 °C) for 2 h before being centrifuged for 20 min at 1200 g at 4 °C. The supernatant was stored at –20 °C until analysed for allergen content.

Der p 1 level was measured using a two-site monoclonal antibody-based enzyme-linked immunosorbent assay (ELISA; Indoor Biotechnologies, Chester, UK) [12]. The standard used to establish the control curve for Der p 1 assay (UVA 93/02) was considered to contain 2500 ng Der p 1/mL (relative to WHO/IUIS *Dermatophagoides pteronyssinus* standard NIBSC 82/518 which has been estimated to contain 12.5 µg Der p 1 per ampoule). Doubling dilutions of this standard extract were used to construct a control curve with each individual assay; the dilutions used were from 250 to 0.5 ng/mL.

Each collected allergen sample was assayed in duplicate, at 1/5, 1/25 and 1/125 dilutions. If at these dilutions the result did not fall on the linear portion of the control curve, the sample was re-assayed at the appropriate dilution. Results were then calculated as µg Der p 1 per gram of fine dust collected (µg/g). Samples which were below the limit of detection of the Der p 1 assay were assigned a value of 0.05 µg/g, the limit of detection of the assay.

Statistics

The analysis was performed using Statistical Package for Social Sciences (SPSS) version 9. The allergen levels in reservoir dust were log normally distributed, so geometric means (GM) and 95% confidence intervals (95% CI) are presented. Comparisons of allergen levels between the groups were made using one-way analysis of variance (ANOVA). Univariate analyses were performed to examine the relationship between each household characteristic and each of the four allergen reservoirs. Following this, a multiple linear regression analysis was

performed for each allergen reservoir, using the stepwise method. The homes were divided into two groups – low allergen, in which all dust reservoirs contained Der p 1 levels less than 2 µg/g, and high allergen (all others). Chi square tests were used to identify individual household characteristics associated with high or low allergen homes. Following this a multiple logistic regression analysis was performed to identify household characteristics that were independent associates for high and low allergen homes, and odds ratios presented.

Results

Der p 1 levels

The results of the Der p 1 levels are shown in Table 1. Der p 1 levels were significantly higher in the mattress than in the other three reservoirs [e.g. the mean level of Der p 1 in the mattress was 1.54-fold (95% CI 1.23–1.92) higher than the Der p 1 level in the LF]. However, there were no differences among Der p 1 levels in the other three reservoirs. Based on the level of Der p 1, the results were divided into four categories for each dust reservoir: < 0.05 µg/g (below the limit of detection of the assay), 0.06–2 µg/g, 2.01–10 µg/g and greater than 10 µg/g. The percentage of homes in each category is shown for each reservoir in Table 1. Twenty per cent of mattresses contained Der p 1 levels greater than 10 µg/g. Only 4.3% of homes contained no detectable Der p 1 in any reservoir. In two-thirds of homes, Der p 1 levels > 2 µg/g were found in at least one reservoir. Three or more reservoirs containing more than 2 µg/g Der p 1 were found in 19.5% of homes. Only 7.4% of homes contained Der p 1 levels above 2 µg/g in all reservoirs, but 40.3% of homes contained at least one reservoir with Der p 1 levels greater than 10 µg/g. There was a large range of Der p 1 levels between homes for each reservoir (Table 1). No statistically significant difference was found among levels of Der p 1 found in dust samples collected in each season (data not shown).

Characteristics of homes

The most common type of home was a three-bedroomed, semi-detached house occupied by two adults, built before 1940. Fewer than 5% of homes contained uncarpeted floors. More than 90% of homes used gas for heating and 88.4% were centrally heated. Twenty-nine per cent of homes used both gas and electricity for cooking. More than a quarter of homes had more than one type of glazing in the house ('mixed' glazing). More than 60% of homes had condensation on the main bedroom windows in winter, and in almost 20% this was described as

Table 1. Der p 1 levels in 564 homes: concentrations (µg/g), ranges and distributions (%)

	LF	S	BF	M
Geometric mean (µg/g)	0.77	0.82	0.7	1.19
95% confidence intervals (µg/g)	0.64–0.92	0.69–0.96	0.58–0.84	0.98–1.45
Range	0.05–215	0.05–450	0.05–310	0.05–1050
(-fold difference)	(4301)	(9000)	(6200)	(21 000)
Der p 1 < 0.05 (%)	23.5	17.2	25.8	20.2
Der p 1 0.05–2 (%)	41.7	50.8	42.2	39.1
Der p 1 2.01–10 (%)	20.9	20.1	16.9	20.7
Der p 1 > 10 (%)	13.9	11.9	15.1	20.0

severe or running. Damp was reported in more than a quarter of all homes surveyed, including 5% of kitchens, 6.4% of main bedrooms and 10.8% of bathrooms.

Household characteristics and Der p 1 levels: univariate analysis

No association was found between Der p 1 levels in any dust reservoir and number of adults living in the house, presence of cigarette smokers, type of fibre used in the carpet and type of fuel used for cooking (data not presented).

There was a highly significant correlation between Der p 1 levels expressed as concentration of allergen per unit weight of dust in µg/g and when expressed as total allergen recovered from the unit area sampled in ng (r ranged from 0.924 to 0.958, $P \leq 0.0001$). The univariate and multivariate analyses were performed with the results expressed in both ways, but there was very little difference between the two, therefore the results are presented as concentration of allergen in µg/g.

Living room floor The strongest association was found with the age of living room carpet ($P < 0.001$). Carpets less than 1 year old contained similar levels of Der p 1 to non-carpeted floors (0.247 µg/g vs. 0.258 µg/g), but carpets more than 5 years old contained 7.25-fold (95% CI 4.48–11.71) higher levels of Der p 1.

The presence of condensation on the bedroom and living room windows was associated with higher Der p 1 levels, as was damp in the main bedroom [1.62 µg/g (95% CI 0.77–3.42) vs. 0.74 µg/g (95% CI 0.62–0.90) $P = 0.03$]. Homes built before 1940 contained 2.41-fold (95% CI 1.34–4.3) higher levels of Der p 1 in the living room floor than those built after 1980. Higher annual income was associated with higher levels of Der p 1 in the living room floor, as were older bedroom carpets. Levels of Der p 1 in the living room carpets in single- and double-glazed homes were very similar. Carpets in houses with 'mixed' glazing contained significantly higher levels of Der p 1 [1.27 µg/g (95% CI 0.89–1.81) vs. 0.67 µg/g (95% CI 0.51–0.99) $P = 0.005$].

Sofa In living rooms where the carpet was more than 5 years old, the Der p 1 level in the sofa was on average 2.56-fold (95% CI 1.63–4.04) higher than in those living rooms where the carpet was less than 1 year old ($P \leq 0.001$). The presence of condensation on the living room window was associated with significantly higher levels of Der p 1 in the sofa [1.13 µg/g (95% CI 0.82–1.55) vs. 0.72 µg/g (95% CI 0.59–0.87) $P = 0.02$]. Damp in the bedroom or condensation on the bedroom walls or windows was associated with higher levels of Der p 1, as were older houses, older bedroom carpets and mixed glazing.

Bedroom floor Bedroom carpets more than 5 years old contained Der p 1 levels 5.12-fold higher (95% CI 1.13–8.54) than those found in carpets less than 1 year old. Houses built before 1940 contained 3.8-fold (95% CI 2.1–6.81) higher levels of Der p 1 in the bedroom carpet than those built after 1980. Bedrooms in which condensation was reported on the walls contained significantly higher levels of Der p 1 in the carpet [2.75 µg/g (95% CI 0.64–11.7) vs. 0.69 µg/g (95% CI 0.57–0.83) $P = 0.049$], but the numbers reporting condensation on the walls were small ($n = 10$). Condensation on bedroom and kitchen windows was associated with higher mite allergen

levels. Damp anywhere in the house was also associated with higher levels, particularly damp in the main bedroom (3.63-fold higher, 95% CI 1.71–7.71). Older living room carpets and not having central heating was associated with higher levels of Der p 1 in bedroom carpets.

Mattress The characteristics most strongly associated with higher Der p 1 levels in the mattress (Table 2) were older homes, damp in any room (2.36-fold difference, 95% CI 1.51–3.67) and not having central heating (threefold difference, 95% CI 1.66–5.59). Condensation on the walls was associated with higher levels, particularly in the bedroom, where Der p 1 levels were 8.74-fold higher (95% CI 2.28–33.45). Having mixed glazing in the home was associated with higher levels than having double-glazing alone. Households with lower annual incomes had higher mite allergen levels in the mattress.

For the last 319 homes visited, the age of the mattress was recorded into one of four categories, less than 1 year, 1–5 years, 5–10 years and greater than 10 years, with levels of Der p 1 shown in Table 3. Levels of Der p 1 in the mattress increased with age and the differences were statistically significant ($P < 0.001$), with mattresses older than 10 years containing on average eightfold higher levels of Der p 1 (95% CI 2.4–26.6) than those fewer than 10 years old.

Household characteristics and Der p 1 levels: multivariate analyses

For the multivariate analysis, all factors that were significantly associated in the univariate analyses, plus factors shown to be associated by other investigators, were included. The results of all five multivariate analyses are shown together in Table 4.

For the living room floor, as in the univariate analysis, higher Der p 1 levels were associated with older carpets, increasingly severe condensation on bedroom windows, increasing income, damp in the main bedroom, older homes and mixed glazing.

Factors associated with higher mite allergen levels in the sofa were: increasingly severe condensation on the bedroom window, having mixed glazing in the house, having a living room carpet greater than 5 years old and increasing age of the house. For the bedroom floor, characteristics of the home associated with higher Der p 1 levels were the presence of damp in the bedroom and condensation on the bedroom windows and older homes.

For the mattress, when the age of the mattress was excluded from the multivariate analysis, factors associated with higher mite allergen levels were: increasing age of the house, using electricity for heating, older living room carpets, damp in the bathroom, increasing numbers of children living in the house and damp in the bedroom and dining room. There was no association with the age of the bedroom carpet. When the analysis was repeated with age of the mattress included (319 cases only) age of the mattress was most strongly associated in the model. Other factors associated with higher Der p 1 levels were presence of condensation on the bathroom walls, damp anywhere in the house, increasing age of the house and living in a terraced house.

Categorization of homes

In order to further analyse the effects of housing characteristics on Der p 1 levels within the home, the houses were divided into

Table 2. Household characteristics associated with higher Der p 1 levels in the mattress – results of univariate analysis

Variable	Category	<i>n</i>	GM, µg/g (95% CI)	<i>P</i> -value
House age	Before 1940	275	1.557 (1.189–2.040)	< 0.001
	1940–60	127	1.606 (1.042–2.477)	
	1960–80	88	0.796 (0.492–1.287)	
	Since 1980	62	0.353 (0.201–0.619)	
Presence of central heating	yes	485	1.048 (0.849–1.293)	< 0.001
	no	65	3.210 (1.723–5.979)	
Condensation on living room window	yes	151	1.643 (1.108–2.437)	0.05
	no	400	1.065 (0.845–1.344)	
Condensation on main bedroom window	yes	349	1.542 (1.193–1.991)	0.001
	no	193	0.778 (0.568–1.065)	
Severity of condensation on main bedroom window	mild	111	1.515 (0.978–2.347)	0.01
	moderate	127	1.582 (1.025–2.444)	
	severe	111	1.522 (0.972–2.382)	
Condensation on bedroom walls	yes	12	10.04 (2.124–47.06)	0.002
	no	539	1.144 (0.935–1.400)	
Condensation on kitchen window	yes	259	1.627 (0.460–2.175)	0.004
	no	292	0.916 (0.696–1.204)	
Condensation on other bedroom windows	yes	201	1.586 (1.129–2.228)	0.035
	no	350	1.022 (0.798–1.310)	
Condensation on other bedroom walls	yes	10	12.906 (2.301–72.398)	0.001
	no	541	1.148 (0.940–1.402)	
Damp in the kitchen	yes	27	4.238 (1.473–12.169)	0.004
	no	524	1.124 (0.917–1.379)	
Damp in the main bedroom	yes	36	4.480 (1.888–10.629)	0.001
	no	518	1.099 (0.896–1.348)	
Damp in other bedrooms	yes	26	4.316 (1.312–14.193)	0.004
	no	525	1.126 (0.920–1.378)	
Damp in the bathroom	yes	59	2.962 (1.540–5.697)	0.002
	no	492	1.077 (0.874–1.326)	
Damp in any room in house	yes	145	2.269 (1.506–3.418)	< 0.001
	no	409	0.962 (0.767–1.206)	
Type of glazing	Single	199	1.223 (0.894–1.671)	0.049
	Double	201	0.874 (0.62–1.232)	
	Secondary	10	1.25 (0.185–8.46)	
	Mixed	145	1.794 (1.227–2.624)	
Annual income	< £10 000	102	2.351 (1.436–3.847)	0.006
	£10–20 000	223	1.007 (0.791–1.468)	
	£20–30 000	134	1.004 (0.715–1.540)	
	> £30 000	86	0.764 (0.472–1.236)	

Table 3. Der p 1 levels in mattresses of different ages, for 319 cases only

Age of mattress	<i>n</i>	GM (µg/g)	95%CI (µg/g)
Less than 1 years	71	0.420	0.248–0.710
1–5 years	152	0.809	0.573–1.142
5–10 years	82	2.548	1.573–4.127
Greater than 10 years	14	7.612	2.478–23.378

two categories to give an overall assessment of their mite allergen content based on the measured levels in the four dust reservoirs sampled (low allergen – all reservoirs less than 2 µg/g, *n* = 187; high allergen – 1 or more reservoir greater than 2 µg/g, *n* = 377).

Chi square tests were then performed to investigate whether individual household characteristics were associated with trends in allergen levels. The results are displayed in Table 5. Factors associated with high allergen homes were: presence and

severity of condensation on bedroom windows, condensation on living room and other bedroom windows and damp anywhere in the house especially in the main bedroom or bathroom. Homes with high levels of mite allergen were also more likely to be older and to contain mixed glazing. Older carpets were more commonly found in homes with high levels, whereas smooth floors were more commonly found in low allergen homes. Heating and cooking fuel, family income, presence of cigarette smokers and total number of occupants showed no association.

Although homes without any condensation on windows tended to contain less mite allergen (*P* < 0.001), 117 of the 377 homes in the high allergen group reported no condensation on windows.

A multiple logistic regression analysis was then performed to identify household characteristics independently associated with homes containing high levels of mite allergen. Older homes were more likely to fall into the high allergen category (OR 2.5, 95% CI 1.34–4.59). The presence of condensation on

Table 4. Multivariate analyses of factors associated with higher levels of Der p 1 for LF, S, BF and M

Variable (adjusted R^2 for model)	LF (0.163) <i>P</i> -value	Sofa (0.086) <i>P</i> -value	BF (0.134) <i>P</i> -value	M (0.123) <i>P</i> -value	M ($n = 319$) <i>P</i> -value
Increasing age of house	0.012	0.038	< 0.001	< 0.001	0.013
Living room carpet older than 5 years	< 0.001	0.004	NA	0.005	NA
Damp in main bedroom	0.010	NA	< 0.001	0.031	NA
Mixed glazing throughout house	0.018	0.001	NA	NA	NA
Increasing severity of condensation on bedroom window	0.002	< 0.001	NA	NA	NA
Condensation on BR window	NA	NA	0.008	NA	NA
Damp anywhere in the house	NA	NA	NA	NA	0.012
Damp in the bathroom	NA	NA	NA	0.017	NA
Damp in the dining room	NA	NA	NA	0.032	NA
Condensation on bedroom walls	NA	NA	NA	0.049	0.002
Use of electricity for heating	NA	NA	NA	0.002	NA
More children in the house	NA	NA	NA	0.021	NA
Terraced house	NA	NA	NA	NA	0.02
Increasing annual income	0.009	NA	NA	NA	NA
Increasing age of mattress	NR	NR	NR	NR	< 0.001

NA, not associated; NR, not relevant.

Table 5. Univariate analysis of factors associated with high allergen homes

Variable	χ^2	<i>P</i> -value
Older homes	19.8	< 0.001
Older living room carpets	19.9	< 0.001
Older bedroom carpets	11.8	0.003
Carpet in living room	7.3	0.026
Condensation on the living room window	4.6	0.032
Presence of condensation on bedroom windows	11.7	0.001
Increasing severity of condensation on bedroom windows	17.5	0.001
Condensation on other bedroom windows	6.1	0.014
Condensation on bedroom walls	5.0	0.025
Damp in any room	8.9	0.003
Damp main bedroom	6.4	0.011
Damp bathroom	5.6	0.018
Mixed glazing	7.6	0.006
Not having double-glazing	4.9	0.027

bedroom windows was more common in homes in the high allergen group (OR 1.79, 95% CI 1.20–2.67), as was damp in the main bedroom (OR 3.78, 95% CI 1.26–11.32), and carpets more than 5 years old (OR 2.19, 95% CI 1.36–3.52).

Characteristics of homes with no detectable mite allergen

Twenty-four homes in the study contained no detectable mite allergen, and several interesting observations can be made about them. When compared to the rest of the homes, the mite allergen-free homes tended to be newer (Chi square test, $P = 0.002$), although five of the 24 were built before 1940. Also the living room carpets tended to be newer (Chi square test, $P = 0.044$), with only two of the living room carpets in this group being greater than 5 years old. In none of the other household characteristics measured did this group vary from the rest of the homes. In particular, half of the mite allergen-free homes reported condensation on the bedroom window, and six of these described it as severe (running). Eight described

condensation on the kitchen window and five on the living room window. None of the houses had damp in the living room or bedroom (the rooms from which the dust samples were collected), but six reported damp in at least one room in the house.

Comparisons were then made between the characteristics of these mite allergen-free homes and homes in which one or more dust reservoir contained greater than 10 µg/g Der p 1 ($n = 227$). Mite allergen-free homes were significantly more likely to be newer ($P < 0.001$), have double-glazing ($P = 0.003$), have newer carpets in the bedroom ($P = 0.05$), have smooth floors ($P = 0.007$) and not to have condensation on the bedroom window ($P = 0.017$).

Discussion

This is the largest study to measure domestic exposure to mite allergens in adults in the UK. We have found that although the mean levels of Der p 1 in reservoir dust in Manchester are below the level of 2 µg/g, the occupants of two in every three homes in Manchester are exposed to high enough levels of Der p 1 in at least one area of the home, to be associated with an increase in the risk of the development of sensitization. Two-fifths of homes contain at least one dust reservoir with Der p 1 levels greater than 10 µg/g. The range of Der p 1 levels found among homes varied by an order of 10^3 . Clearly, mite allergens levels in Manchester are high enough to be associated with the development of sensitization. It is therefore important to identify household factors associated with high mite allergen levels to devise an appropriate strategy to reduce them.

Some information collected was difficult to analyse, such as cooking fuel, as many homes used both gas and electricity to cook, and carpet fibre type, as more than one-third of occupants did not know this. More than a quarter of homes had dampness in at least one room, and most homes had condensation, particularly on the bedroom window in winter.

Older homes contained higher levels of Der p 1. It has commonly been supposed that modern, more energy-efficient

houses would have a higher absolute indoor humidity as a result of reduced ventilation, making them more suitable for proliferation of dust mites, resulting in higher Der p 1 levels. This argument is not supported by our data; on the contrary the reverse appears to be the case. There are several possible explanations for this. Better insulation in newer homes may be associated with a higher indoor temperature as well as a higher absolute humidity, resulting in RH levels being the same or lower than older houses. Furthermore, for the same RH, higher indoor temperatures are less conducive to mite growth. Therefore it is possible that increased insulation with resultant changes in temperature, humidity and ventilation makes the home less suitable for mite population growth. In this geographical area, the outdoor climate is such that even when homes are well ventilated, the indoor RH is high enough to support mite proliferation, and therefore factors other than RH limit mite population expansion and mite allergen levels.

Older carpets are independent risk factors for higher mite allergen levels. Carpets form an excellent trap for fallen particles that provide food for dust mites. Vacuum cleaners are ineffective at removing dust in the pile of the carpet and have no significant effect on mite allergen levels [13]. With time, both the volume of dust within the carpet and the concentration of mite allergens within that dust increases. Carpets less than 1 year old had similar mite allergen levels to smooth floors. The three categories into which the age of the carpet was divided did not allow us to determine at what age mite allergen levels reach a plateau in a carpet, if indeed they do. However, almost half of carpets over 5 years old contained Der p 1 levels greater than 2 µg/g. It is clear from these data that to keep mite allergen levels in the floor low it is important to either replace the carpets at 1- to 2-year intervals or to have a smooth floor. Similarly, once a new mattress has become colonized with house dust mites, dust and stable mite allergen accumulate with time. It is therefore not surprising that increasing age of the mattress is a major risk factor for higher Der p 1 levels in the mattress.

Reported damp in the main bedroom was an independent risk factor for higher Der p 1 levels in the living room carpet, the bedroom carpet and the mattress. Damp in other rooms of the house was also an independent risk factor for higher mite allergen levels in the mattress. Damp can arise as a result of faulty guttering, pipes or ill-fitting windows, allowing brickwork to become persistently wet. This may result in higher indoor absolute humidity and may make conditions more favourable to mite survival. It is, however, interesting to note that a quarter of homes with no detectable mite allergen contained damp somewhere in the house, although none had damp in the rooms from which the dust samples were collected.

Condensation on windows and walls was associated with higher Der p 1 levels. The interior surface temperature of the windowpane is lower for single-than double-glazed windows and so double-glazed homes were significantly less likely to have condensation on any windows and when present it tended to be less severe. The presence of condensation on windows as a marker of absolute indoor humidity has to be taken in the context of the type of glazing. However, in contrast to a recently published study from Sweden [14], the absence of condensation on windows is not a marker of low mite allergen levels in Manchester homes as 31% of occupants of homes in the high allergen group denied condensation.

Mixed glazing in the house was an independent risk factor for higher mite allergen levels in the living room carpet and the sofa. Most homes in this category had a mixture of single- and double-glazed windows. It is tempting to speculate that ill-fitting or rotten single-glazed window frames, which may have been associated with dampness in the house, had been replaced with double-glazed units in some of the rooms. It is possible that the presence of mixed glazing in the house may be indicative of previous problems with damp.

There are 16 published studies from around the world which have examined the relationship between mite allergen levels and housing characteristics [8, 9, 15–28], some of which were too small to perform multivariate analyses [18–21, 27] and some studied homes of asthma patients only [18–21, 23]. Although housing designs and climates are very different in different parts of the world, some common themes have emerged.

Only three of these studies identified indoor RH as an independent predictor of mite allergen levels in multivariate analyses [17, 24, 25] and four found a linear association [16, 18, 19, 26]. Four of the five studies in which age of the carpet was measured found older carpets to contain higher mite allergen levels in a multivariate analysis [8, 16, 24, 25], similarly for five of the seven studies in which the age of the mattress was measured [8, 9, 16, 17, 25]. Of the 12 studies in which the presence of damp was recorded, five studies found it to be associated with higher levels in a multivariate analysis [9, 17, 22, 25, 26], and four found an association in the univariate analysis [16, 19–21]. The association between older homes and higher levels of mite allergen was not clear, although different studies used different age bandings for the homes. Carpets generally contained higher mite allergen levels than smooth floors.

Clear data exist on the effectiveness of some methods of reducing exposure to mite allergen levels, such as having smooth floors and encasing all bedding in mite-proof materials and these measures, once installed, have been shown to remain effective over long periods of time [29]. From these data and that produced by other groups some suggestions could be made to patients with asthma who wish to incorporate mite allergen avoidance into their asthma treatment plan. Household characteristics such as older homes (especially those built before 1940), older carpets (especially those greater than 5 years old), older mattresses, the presence and the severity of condensation on windows and the presence of damp are associated with higher Der p 1 levels. It is clear that it is not possible to modify some of these factors (e.g. age of house), nor is it affordable to change carpets every 1–2 years. It would, however, be appropriate to suggest the repair of faults in homes with damp and to improve ventilation to combat condensation. The advice might include living in a new home (post-1980) with double-glazing and smooth floors but no damp or condensation and using mite-proof encasings for the mattress and bedding.

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