

House dust-mite allergen and cat allergen variability within carpeted living room floors in domestic dwellings

Abstract Exposure to allergens from house dust-mites (Der p 1) and domestic cats (Fel d 1) is associated with symptom severity in atopic subjects with asthma and rhinitis. Assessment of allergen exposure in the domestic environment is normally determined by measurement from a single floor site. We determined the variability of these allergens and protein throughout the whole living room floor area. Dust samples were collected from 1 m² areas from 16 carpeted living room floors in Wellington, New Zealand, and analyzed for concentrations of Der p 1 and Fel d 1. Mean coefficients of variation for Der p 1 and Fel d 1 were 53.1% (range: 28.5–136.8) and 65.6% (range: 28.5–131.0), respectively. This study has demonstrated a large variation of house dust-mite and cat allergens within living room floors and thus assessment of a single sampling site may not be representative of an individual's exposure risk. House dust-mite and cat allergen levels from the center of the room, in front of a couch or chair, or from a corner of the room are similar to mean levels from the whole room. These sites may thus be representative of the whole living room floor in large-scale epidemiological studies.

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Practical Implications

Normally a single site from the floor is sampled for assessment of house dust-mite and cat allergen exposure. This study has shown a large variation of these allergens within living rooms and thus allergen assessment from a single site may not be representative of an individual's exposure risk. However, for large-scale epidemiological studies, a single site from the center of the room, in front of a couch or chair, or from a corner of the room is representative of the whole living room floor.

Introduction

Exposure to high levels of allergens of the house dust-mite (Der p 1) and cat (Fel d 1) is associated with exacerbation of symptoms in allergic subjects with asthma and rhinitis. Der p 1 and Fel d 1 levels in reservoir dust > 10 and 8 µg/g, respectively, have been associated with increased risk of acute attacks in sensitized individuals (Platts-Mills et al., 1997). Traditionally, environmental allergen levels have been assessed by analysis of reservoir dust sampled from a single floor site within a room, on the assumption that this is representative of the whole room.

Two previous studies have determined the variability of distribution of Der p 1, in rooms in the domestic environment. Tovey (1995) from Sydney, Australia,

measured Der p 1 in dust collected from every half metre square within 10 rooms. From the data presented from one bedroom of 10 room floors studied, we calculated their coefficient of variation to be 31.7%, with Der p 1 levels ranging from 17 to 85 µg/g. In a similar study from Manchester, UK, Simpson et al. (1998) found mean coefficients of variation of 80.2 and 88.7% for Der p 1 distribution in 1 m² sections within six living room floors and nine bedroom floors, respectively.

The distribution of Der p 1 levels within rooms is likely due to a host of, as yet unknown factors. The degree of variability of allergen levels within a room may be due to differences in Der p 1 levels in reservoir dust encountered in different geographic areas. For instance, geometric mean living room floor Der p 1

levels in Wellington, New Zealand, are, on average, 17-fold higher than in Manchester, UK (Simpson et al., 1998; Wickens et al., 1997). The aim of this study was to determine the variability of Der p 1 within living rooms in Wellington homes. Additionally, we studied the variability of Fel d 1 distribution in living room floors, which, to our knowledge, has not previously been determined.

Materials and methods

Dust samples were collected from carpets of 16 living room floors of staff and students of the Wellington School of Medicine by one of the authors (RL). Each living room floor carpet was divided into 1 m² sections, with a wall as a reference starting point. Any sections remaining, < 1 m² in size, were not sampled. Dust was also not sampled from underneath heavy items of furniture, such as cabinets or bookcases. From each mapped 1 m² area, dust was collected by vacuuming for 1 min using a Hitachi CV-2500 vacuum cleaner (1100 W; Hitachi, Tokyo, Japan) as previously described (Wickens et al., 1997). A diagram was drawn of each room, marking the mapped 1 m² areas, and the position of furniture, windows, and door entrances. The study was approved by the Wellington Central Regional Ethics Committee.

Collected dust samples were stored at -20°C, then sifted through a 425 µm steel mesh sieve, and the weight of the fine sifted dust recorded. The sifted dust samples were extracted (100 mg in 1 ml of Tween-20 containing phosphate-buffered saline for 30 min at room temperature), and Der p 1 and Fel d 1 levels in the supernatants measured by established double-monoclonal antibody enzyme-linked immunosorbent assay methodologies using a commercial kit from Indoor Biotechnologies Ltd, Cardiff, UK (Chapman et al., 1988; Luczynska et al., 1989; Siebers et al., 1997). Between-batch coefficient of variation for allergen assay is approximately 10% in our laboratory.

Due to log-normal distribution, Der p 1 (µg/g) and Fel d 1 (µg/g) levels are presented as geometric mean. We calculated coefficients of variation as s.d./mean × 100%. Values were compared by Student's *t*-test or ANOVA, a *P*-value of 0.05 or less was considered significant.

Results

There was a strong correlation between concentration, expressed per gram of fine dust, and content, expressed per m², for Der p 1 and Fel d 1 (*r* = 0.92 and 0.95, respectively on log-transformed data). Results are therefore presented for concentration only. There was a statistically significant correlation (*r* = 0.33; *P* = 0.0001) between Der p 1 and Fel d 1, on log-transformed µg/g values. Similarly, there was a signi-

Table 1 Derp 1 (µg/g) in 16 living room floors

Living room	Number of 1 m ² sites	Geometric mean Der p 1	Range of values	Coefficient of variation (%)	Fold difference
1	12	75.7	17.7–221.6	65.3	12.5
2	12	25.7	5.7–80.7	75.1	14.2
3	8	49.9	23.4–96.2	41.4	4.1
4	14	29.1	12.0–61.1	50.1	5.1
5	15	5.8	2.5–10.9	41.9	4.4
6	9	28.7	21.6–49.6	29.7	2.3
7	9	82.6	53.8–121.0	28.5	2.2
8	12	56.7	30.7–115.4	41.1	3.8
9	9	6.9	4.9–12.3	36.1	2.5
10	10	31.4	6.3–58.5	51.9	9.3
11	10	1.7	0.6–3.8	45.1	6.3
12	12	59.8	29.3–122.9	43.7	4.2
13	10	8.8	2.2–24.7	63.3	11.2
14	9	53.1	24.2–114.7	50.6	4.7
15	30	1.5	0.1–25.3	136.8	253.0
16	12	102.7	57.5–212.1	48.8	3.7

Table 2 Fel d 1 (µg/g) in 16 living room floors

Living room	Number of 1 m ² sites	Geometric mean Fel d 1	Range of values	Coefficient of variation (%)	Fold difference
1	12	101.8	29.0–493.4	107.6	17.0
2	12	50.6	8.9–207.4	80.3	23.2
3	8	40.2	13.8–131.4	77.2	9.5
4	14	9.3	3.1–31.1	64.6	10.0
5	15	3.8	0.8–31.0	131.0	38.8
6	9	1.8	1.0–2.9	30.6	2.9
7	9	17.4	7.3–35.2	50.0	4.8
8	12	24.1	6.3–109.5	90.3	17.4
9	9	2.2	1.3–3.3	33.7	2.5
10	10	21.5	7.6–50.3	51.1	6.6
11	10	3.5	2.3–5.2	28.5	2.3
12	12	810.3	332.4–2169.6	59.2	6.5
13	10	271.9	96.6–692.3	69.2	7.2
14	9	11.9	5.5–29.6	60.1	5.4
15	30	47.0	1.3–190.8	75.6	146.8
16	12	2621.7	1373.9–4881.5	40.2	3.6

ficant correlation between the total amount of dust collected per m² and log µg/g Der p 1 (*r* = 0.25; *P* = 0.0004), but not for log µg/g Fel d 1 (*r* = 0.03; *P* = 0.73).

A mean of 12 samples (range: 8–30) were obtained per living room floor (*n* = 16). Tables 1–3 show the geometric mean and the range of values for Der p 1, Fel d 1, and total dust weights found within each of the living room floor. Mean coefficients of variation (range of values) for Der p 1, Fel d 1, and total dust weight were 53.1 (28.5–136.8), 65.6 (28.5–131.0), and 44.1% (23.7–64.8), respectively. There was no statistically significant correlation between the number of sites sampled from each living room floor and the variability of Der p 1 (*r* = 0.07; *P* = 0.79) or Fel d 1 (*r* = 0.31; *P* = 0.24) within each living room floor. Nor was there a statistically significant correlation between geometric mean Der p 1 (*r* = 0.18; *P* = 0.51) and Fel d 1 (*r* = 0.23; *P* = 0.39) concentrations of each living

Table 3 Total dust weight (g) per 1 m² in 16 living room floors

Living room	Number of 1 m ² sites	Mean dust weight	Range of values	Coefficient of variation (%)	Fold difference
1	12	0.87	0.36–1.38	36.5	3.8
2	12	0.97	0.36–1.95	51.4	5.4
3	8	0.93	0.53–1.51	33.3	2.8
4	14	2.44	0.91–6.21	63.7	6.8
5	15	0.54	0.21–1.04	40.5	5.0
6	9	0.56	0.39–0.80	26.2	2.1
7	9	0.77	0.51–1.02	23.7	2.0
8	12	1.17	0.56–1.85	32.9	3.3
9	9	2.06	1.07–4.29	48.7	4.0
10	10	1.25	0.66–1.73	28.8	2.6
11	10	0.68	0.39–0.99	32.5	2.5
12	12	2.40	0.95–6.01	58.6	6.3
13	10	0.51	0.22–1.27	64.8	5.8
14	9	1.60	0.75–3.55	54.9	4.7
15	30	1.95	0.84–5.81	54.1	6.9
16	12	0.78	0.14–1.29	55.6	9.2

Table 4 Der p 1 and Fel d 1 levels from three sites within 16 living room floors, and from the whole living room floor

	Der p 1*	Fel d 1*
Center of room	20.1 (11.3–35.8)	19.2 (5.7–64.5)
Front of couch/chair	26.2 (13.2–53.3)	32.4 (10.5–102.1)
One corner of room	17.9 (6.0–53.2)	20.4 (6.6–61.5)
Whole room	16.5 (12.8–21.2)	32.5 (24.2–43.6)

*Geometric mean $\mu\text{g/g}$ (95% confidence interval).

room floor with the corresponding living room floor coefficient of variation.

Der p 1 and Fel d 1 concentrations of each 1 m² area from each living room floor were plotted, and compared visually in relation to position of furniture, windows, and doors. No apparent patterns of distribution were visually discernible. Values from three different sites within each living room were then compared with each other, and to the geometric mean level from the whole living room floor. Table 4 shows the values obtained from the center of the living room floor, in front of the couch or chair, from one corner of the living room floor, and from the whole living room floor. Comparison of results from these three sites to the geometric mean level for the whole living room floor revealed no statistically significant differences ($P = 0.22$ and 0.14 , respectively for Der p 1 and Fel d 1; ANOVA).

Discussion

Levels of Der p 1 and Fel d 1 are widely measured worldwide in epidemiological studies of atopic sensitization and asthma symptoms, as well as in allergen avoidance studies. Normally, a central area within the room is sampled, with the assumption that this is representative of the whole room. This study,

and a previous study (Simpson et al., 1998), has shown that this assumption is correct for Der p 1. Additionally, this study has shown that this is also true for Fel d 1.

However, while there were no significant differences between the geometric mean living room floor levels, and corresponding levels from the center of the room (the usually sampled site), variations within rooms were large. For example, coefficients of variation ranged from 36.1 to 136.8% for Der p 1. This would not normally be of importance in large-scale epidemiological studies. However, when assessing an atopic patient's exposure, a single measurement within the living room may not accurately reflect the patient's risk to the measured allergen. For instance, in one living room the lowest Der p 1 concentration was $0.1 \mu\text{g/g}$, which is below the epidemiological level for sensitization, while the highest Der p 1 concentration was $25.3 \mu\text{g/g}$, a level which is suggestive of being able to induce symptoms in house dust-mite sensitized individuals (Platts-Mills et al., 1997).

Simpson et al. (1998) studied Der p 1 variability within carpets from living room floors and bedroom floors in Manchester, UK, and found mean coefficients of variation in Der p 1 levels of 80.2 and 88.7%, respectively. They compared this with the only previously reported study by Tovey (1995) from Sydney, Australia, where the coefficient of variation from one of 10 studied room floors was calculated to be 31.7%. Simpson et al. (1998) attribute the differences in coefficients of variation between the two centers to the vast differences in Der p 1 levels between Manchester, UK and Sydney, Australia. However, Der p 1 levels in Wellington, New Zealand, are high, and similar to those in Sydney, Australia (Marks et al., 1995; Wickens et al., 1997). We were unable to establish a correlation between individual geometric mean allergen concentrations and the corresponding coefficient of variation within living room floors. Furthermore, it is not possible to ascertain from Tovey's study (1995) what the coefficients of variation were for the other nine room floors in his study.

The major cat allergen, Fel d 1, is widely distributed within the community, even in domestic dwellings where cats are not resident (Sawyer et al., 1998). Due to its physical and aerodynamic properties, Fel d 1 can even be detected in cat-free areas (Siebers et al., 1999). To our knowledge, no studies have determined variability of Fel d 1 within carpeted room floors. Our study has shown a wide variability for Fel d 1, similar to Der p 1. Even households without resident cats had detectable Fel d 1 levels, and with similar coefficients of variation compared to households with resident cats (data not shown). Although no consistent pattern of Fel d 1 distribution was apparent, two tenants were able to specify where their cat's 'favorite place' in the

living room was. In both cases, these 'favorite places' had Fel d 1 levels above the 75th percentile for the living room floor, suggesting that high Fel d 1 levels may be found where the cat spends most of its time in the living room.

Interestingly, we found significant positive associations between Der p 1 concentrations and total weights of dust collected from living room floor dust samples. Both dust and allergen levels build up in carpets over time, and it is only with intensive vacuuming that allergen levels decrease significantly (Adilah et al., 1997). Therefore, these associations between concentrations of Der p 1 and dust weight may reflect a gradual continuous build up over time as a result of infrequent cleaning schedules.

In conclusion, this study has demonstrated a large variability of Der p 1 and Fel d 1 in carpets in living room floors from domestic dwellings in Wellington,

New Zealand. This variation could not be explained by the concentrations of allergens within living room floors, nor by the size of the room. For large-scale epidemiological studies a single sampling site from the center of the room, in front of a couch or chair, or from one corner of the living room is representative of the whole living room floor, but not for assessment of an individual's exposure risk.

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References

- Adilah, N., Fitzharris, P., Crane, J. and Siebers, R.W. (1997) The effect of frequent vacuum cleaning on the house dust mite allergen, Der p 1 in carpets: a pilot study., *N. Z. Med. J.*, **110**, 438–439.
- Chapman, M.D., Aalberse, R.C., Brown, M.J. and Platts-Mills, T.A.E. (1988) Monoclonal antibodies to the major feline allergen Fel d 1. II. Single step affinity purification of Fel d 1, N-terminal sequence analysis, and development of a sensitive two-site immunoassay to assess Fel d 1 exposure., *J. Immunol.*, **140**, 812–818.
- Luczynska, C.M., Arruda, L.K., Platts-Mills, T.A.E., Miller, J.P., Lopez, M. and Chapman, M.D. (1989) A two-site monoclonal antibody ELISA for the quantification of the major Dermatophagoides spp. allergens, Der p 1 and Der f 1., *J. Immunol. Methods*, **118**, 227–235.
- Marks, G.B., Tovey, E.R., Peat, J.K., Salome, C.M. and Woolcock, A.J. (1995) Variability and repeatability of house dust mite allergen measurement: implications for study design and interpretation., *Clin. Exp. Allergy*, **25**, 1190–1197.
- Platts-Mills, T.A.E., Vervloet, D., Thomas, W.R., Aalberse, R.C. and Chapman, M.D. (1997) Indoor allergens and asthma: report of the Third International Workshop., *J. Allergy Clin. Immunol.*, **100**, S2–S24.
- Sawyer, G., Kemp, T., Shaw, R., Patchett, K., Siebers, R., Lewis, S., Beasley, R., Crane, J. and Fitzharris, P. (1998) Biologic pollution in infant bedding in New Zealand: high allergen exposure during a vulnerable period., *J. Allergy Clin. Immunol.*, **102**, 765–770.
- Siebers, R., Luey, B., Crane, J. and Fitzharris, P. (1997) The effect of temperature and buffer on the extraction of Der p 1 from dust., *J. Allergy Clin. Immunol.*, **100**, 580.
- Siebers, R., Weinstein, P., Fitzharris, P. and Crane, J. (1999) House-dust mite and cat allergens in the Antarctic., *Lancet*, **353**, 1942.
- Simpson, A., Hassall, R., Custovic, A. and Woodcock, A. (1998) Variability of house-dust-mite allergen levels within carpets., *Allergy*, **53**, 602–607.
- Tovey, E. (1995) Mite allergen measurement. In: Tovey, E., Fifoot, A. and Sieber, L. (eds) *Mites, Asthma and Domestic Design II*, Sydney, University Printing Service, 14–18.
- Wickens, K., Siebers, R., Ellis, I., Lewis, S., Sawyer, G., Stone, L., Kent, R., Slater, T., Crothall, A., Trethowen, H., Pearce, N., Fitzharris, P. and Crane, J. (1997) Determinants of house dust mite allergen in homes in Wellington, New Zealand., *Clin. Exp. Allergy*, **27**, 1077–1085.