

Cat allergen (Fel d 1) levels on school children's clothing and in primary school classrooms in Wellington, New Zealand

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Background: New Zealand has a high prevalence of the major allergic diseases including asthma, rhinitis, and eczema, and cat ownership is common, with more than 50% of homes containing a cat.

Objective: The study was designed to examine the levels of cat allergen (Fel d 1) in the primary school environment, both on floors and on children's clothing.

Methods: We collected and analyzed dust samples from 11 school classrooms and from 202 children's garments using vacuum sampling and two-site monoclonal antibody ELISA, respectively. Environmental variables were identified by questionnaire.

Results: The geometric mean level of Fel d 1 in classrooms was 2.61 $\mu\text{g}/\text{gm}$ (95% confidence interval, 1.28 to 3.84); however, seven classrooms had a floor sample with Fel d 1 greater than 8 $\mu\text{g}/\text{m}^2$. Carpeted floor levels at 2.21 $\mu\text{g}/\text{gm}$ (1.28 to 3.84) were considerably higher than those on uncarpeted floors, at 0.33 $\mu\text{g}/\text{gm}$ (0.1 to 1.14). Floor levels and pupil cat ownership rates were positively correlated ($r^2 = 0.93$, $p = 0.0003$). Children from homes with cats carried allergen on their clothes (mean Fel d 1, 6.10 μg per garment compared with non-cat owners (0.72 μg per garment). Wool and polyester garments contained more Fel d 1 than cotton clothing. Girls' clothing had significantly higher levels of allergen than did that of boys, even after controlling for cat status and fabric differences.

Conclusions: Carpeting should be discouraged in environments such as schools and child care centers, where children spend considerable time. Transport of Fel d 1 on clothing from the domestic to the school environment is a major source of classroom cat allergen. (*J Allergy Clin Immunol* 1997;100:755-9.)

Key words: cat, Fel d 1, schools, allergen, clothing, carpet

New Zealand and Australian children have a high prevalence of the common allergic diseases including asthma, eczema, and allergic rhinitis.¹⁻³ There is good evidence that these diseases are increasing in many

Abbreviation used

CI: Confidence interval

countries and that changes in the environment may be an important contributing factor.⁴⁻⁶

Exposure to high levels of allergens, especially early in life, has been associated with an increased risk of developing sensitization to that allergen.⁷⁻⁹ Individuals who have become sensitized to house dust mite and cat, as detected by the presence of specific IgE to these allergens, have an increased risk of developing asthma, whereas those sensitized to the seasonal allergen grass pollen do not.^{10, 11}

Domestic cat ownership is common in New Zealand. Although no national statistics are available, a recent study found that 63% of 12-year-olds living in New Zealand lived in a home with a cat compared with 23% in Sweden, 42% in South Africa, and 29% in Wales.³ A recent study of 7- to 9-year-old children in Wellington found that 57% lived in a household with a cat.¹²

Previous studies have shown that Fel d 1 is a relatively stable molecule and is associated with a range of particle sizes including a proportion less than 2.5 μm in diameter. These smaller particles remain airborne even in undisturbed conditions and are readily transportable. Several studies have demonstrated significant levels of Fel d 1 in a variety of cat-free public buildings, including schools.¹³⁻¹⁵ Findings suggest the hypothesis that this may be due at least in part to allergen transport on the clothing of cat owners.¹⁶

Because young children are exposed to the indoor school environment for prolonged periods, exposure to high levels of cat allergen at school may be a significant factor in the development and maintenance of asthma and allergic rhinitis among school children.

METHODS

Ten primary schools from the Wellington city area were contacted initially by telephone and subsequently by letter and asked to participate in a study to quantitate Fel d 1 levels on classroom floors and on the clothing of 7- to 9-year-old children. One school declined to participate because of concerns that the large number of ethnic groups in the school would make obtaining genuinely informed consent difficult. Before our visit to the school, written consent was obtained

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TABLE I. Fel d 1 level and cat status

Cat status	Mean μg per garment (95% CI)	Mean $\mu\text{g/gm}$ (95% CI)
Subject's cat (<i>n</i> = 111)	6.10* (4.05-9.18)	78.78* (40.94-150.42)
Neighbor's cat (<i>n</i> = 16)	0.55 (0.30-1.04)	14.17 (7.8-25.6)
No cat in home (<i>n</i> = 70)	0.72* (0.51-1.01)	10.95* (8.4-14.19)

**p* < 0.001.

from each child's parent or caregiver for participation in the study.

Questionnaires were administered to the head teacher or building custodian to obtain information on building characteristics and to the pupils regarding their pet ownership. The school visits took place in August 1995 (winter). For three children it was not possible to classify cat ownership, and these were excluded from relevant analysis (Table I).

The classroom chosen was that containing the greatest number of 8-year-old children. Dust was collected by standardized method from two sites within the classroom: at the entrance to the room and in the center of the room. If both of these sites were carpeted, a third sample was taken from an uncarpeted area if such a site existed. Floors were vacuumed with a Hitachi 2500, 1000 W vacuum cleaner (Hitachi, Singapore) for 1 minute over an area of 1 m² for carpeted sites and over an area of 2 m² for noncarpeted sites, into a 25 μm mesh nylon bag.

Samples were collected from clothing with the use of a method based on that described by Enberg and colleagues.¹⁶ Children were asked to remove the outer garment of clothing worn on the upper half of the body. This garment was vacuumed for 90 seconds on the back and 90 seconds on the front. The arms were not vacuumed. The type of garment was noted and fabric type identified, usually from the garment label. For 27 garments, it was not possible to definitively identify fabric type and/or garment type, or these were not recorded. These garments were excluded from the relevant analysis (Tables II and III).

Dust was sieved (425 μm), aliquoted, and stored at -18°C before assay. Cat (Fel d 1) allergen content was assayed by a two-site monoclonal antibody ELISA developed by Chapman et al.¹⁷ Twofold or fourfold sample dilutions (1/50 to 1/1600) were assayed. Reference Fel d 1 standard (1.6 U Fel d 1/ml; 1 U = 4 μg protein) was used at serial dilutions from 1:80 (20 to 0.04 mU/ml). Plates were read with an ANTHOS ELISA microplate reader and analyzed with *Delta Soft11*® (Macintosh version). Duplicates that differed by greater than 10% were rejected. The mean coefficients of variation of the assay were 5.7% (intra-assay) and 6.3% (interassay) with the use of twofold dilutions. Allergen levels are reported in micrograms per gram and micrograms per garment (where appropriate).

Statistical analysis was done with SAS (SAS Institute, Inc., Cary, N.C.). Allergen concentrations were positively skewed with an approximately log normal distribution. Calculations were performed on log-transformed data, and results were expressed as geometric means (mean) and 95% confidence interval (CI) of the mean. Samples with undetectable levels of Fel d 1 were entered as 0.01 $\mu\text{g/gm}$ (below the detection limit of the assay) to avoid zero values. The Student's *t* test or analysis of variance was used to test the level of significance

between variables. For differences between groups, significance was tested at the 95% level. Multiple regression analysis was used to test possible associations between Fel d 1 levels and environmental parameters.

Ethical approval for the study was obtained from the Central Regional Health Authority Wellington Ethics Committee.

RESULTS

Floor samples were collected from eleven classrooms in nine primary schools. Questionnaire information and garment dust were collected from 191 of the 274 children eligible to participate in the study (70% response rate). Eleven additional children, from another classroom from which no floor sample was available, were also sampled. These 11 samples were included in the clothing analysis, providing a total sampled number of 202 garments, but were excluded from the floor correlation analysis.

Pets

Fifty-five percent of children kept one or more cats at home, 28% kept dogs, 13% kept birds, and 22% kept other animals. Sixteen children (8%) had no cat of their own but said that a neighbor's cat came inside their home. Thus 63.4% of children came from homes where a cat was regularly indoors.

Clothing

Allergen measurements were obtained from 200 of the 202 sampled pieces of upper body clothing (garments). For the other two garments there was inadequate dust for analysis. The mean weight of dust collected from garments was 0.069 gm (95% CI, 0.06 to 0.08). Fel d 1 was detectable in all analyzed samples.

Cat ownership was the major determinant of clothing Fel d 1, with the mean levels on the clothing of children who kept cats being significantly higher than those of children who did not (Table I). Garments from children with two household cats had higher levels (18.91 μg per garment) than those from children with one cat (3.71 μg per garment) (*p* < 0.001).

Most children with cats (83%) allowed the cat to enter their bedroom. It is interesting that those children who stated that the cat was kept out of the bedroom showed lower levels of clothing Fel d 1 (*p* < 0.05, with mean levels of 2.42 μg per garment, 95% CI 0.97 to 6.07) than those whose cats entered their bedrooms (7.89 μg per garment, 95% CI 4.96 to 12.53). Fel d 1 concentrations were 33.4 and 96.84 $\mu\text{g/gm}$, respectively (*p* < 0.01).

None of the participating schools required the children to wear uniforms, hence a variety of different garments were vacuumed: sweatshirts (50%), Polarfleece jackets/tops (16%), knitted jerseys (16%), long-sleeved shirts (6%), and miscellaneous garments (12%).

Both the total weight of dust and Fel d 1 levels varied on different garments and fabrics. The difference between types of garments (Table II) showing higher levels in Polarfleece garments and knitted jerseys than in sweatshirts was partly confounded by fabric type. Wool

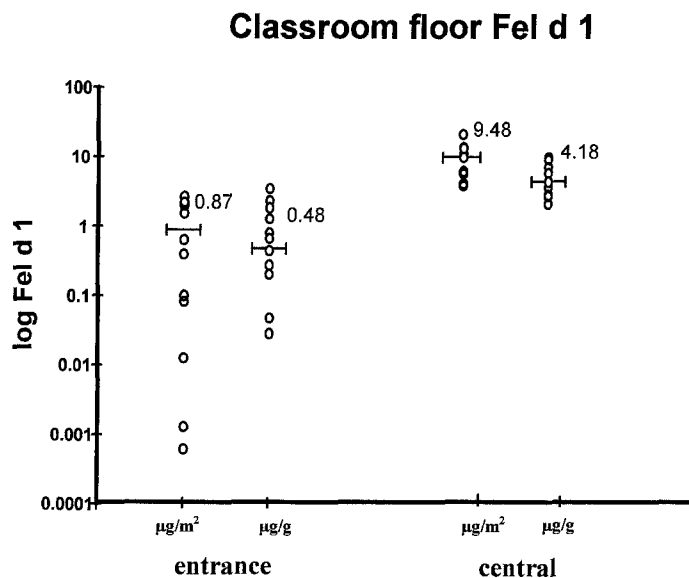


FIG. 1. Fel d 1 ($\mu\text{g}/\text{gm}$ and $\mu\text{g}/\text{m}^2$) at the classroom entrance and on the central carpet. The geometric mean is marked and stated.

TABLE II. Garment type

	N	Weight of dust from shirt (gm)*	Fel d 1 (μg per shirt)	Fel d 1 ($\mu\text{g}/\text{gm}$)
Sweatshirts	100	0.054 (0.046-0.064)	1.49†‡ (1.02-2.17)	27.55§ (20.00-37.95)
Polar fleece tops/jackets	33	0.23 (0.178-0.304)	13.17† (6.24-27.80)	56.61§ (29.93-107.06)
Knitted jerseys	32	0.12 (0.091-0.163)	5.25‡ (2.45-11.26)	43.21 (22.82-81.80)
Long-sleeve shirts	10 (12)¶	0.02 (0.012-0.04)	2.13 (0.52-8.69)	71.53 (22.04-232.13)

*Mean (95% CI).

† $p < 0.001$.

‡ $p < 0.005$.

§ $p < 0.05$.

¶Two of the long sleeve shirts yielded inadequate dust for analysis.

and polyester clothing revealed higher Fel d 1 levels than did cotton garments (Table III). Unclassified garment and fabric types ($n = 29$) were excluded from this analysis. An unexpected difference ($p = 0.04$) was found in mean Fel d 1 levels detected on boys' clothing ($1.73 \mu\text{g}/\text{gm}$; 95% CI, 1.15 to 2.61) compared with girls' clothing ($3.28 \mu\text{g}/\text{gm}$; 95% CI, 2.08 to 5.17). The reason for this significant sex difference was not clear. Cat ownership rate among girls and boys was identical. Despite the advent of unisex clothing, girls and boys did wear slightly different clothing and fabric types. However, even after controlling for cat ownership status and fabric type, sex remained an independent determinant of garment Fel d 1, with girls having 1.79 times (95% CI, 1.39 to 3.00) the levels of Fel d 1 on their clothing than boys.

School environment

The classrooms involved in this study were relatively similar in age, construction materials, ventilation, and

heating systems. The classrooms were 11 to 50 years old, had iron roofs, concrete or timber walls, wooden floors, opening windows, and no central heating. In all except one school, heating was controlled locally in the classroom, usually with gas as an energy source. All classrooms had at least one carpeted site (the center of the room), with four classrooms having wall-to-wall carpet. Although two of the nine schools had a "school cat," only one school admitted that a cat regularly entered the study classroom; cat entry was stated to be less than once per week.

Twenty-six dust samples were collected from up to three different sites in each of the 11 classrooms (Fig. 1). Clearly, there are significant differences in Fel d 1 at the different sites. The difference in mean (95% CI) Fel d 1 between the classroom entrance (site 1, $0.69 \mu\text{g}/\text{gm}$ [0.3 to 1.57]) and the central carpet (site 2, $4.22 \mu\text{g}/\text{gm}$ [2.61 to 6.83]) remained significant after controlling for floor type ($p = 0.004$). Carpeted floor sites,

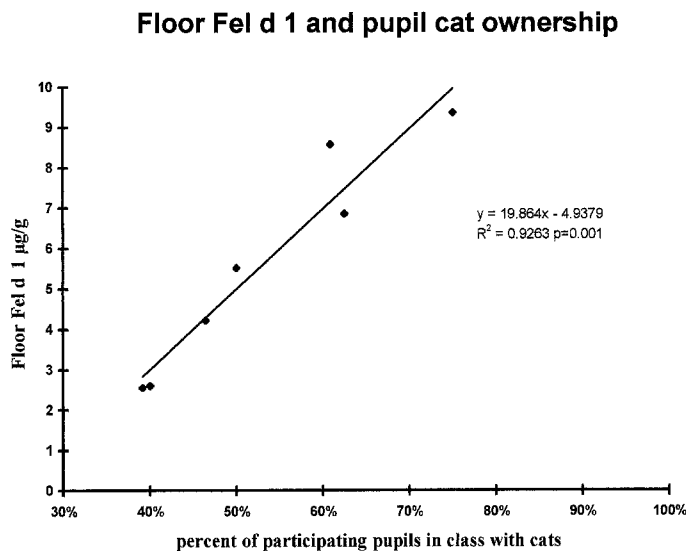


FIG. 2. Linear correlation of the central classroom floor Fel d 1 levels ($\mu\text{g/gm}$) with the percentage of pupils in each classroom with domestic cats.

TABLE III. Fabric type

	<i>N</i>	Total weight of dust (gm)*	Fel d 1 (μg per shirt)*	Fel d 1 ($\mu\text{g/g}$)*
Polyester-cotton blend	63	0.066 (0.055-0.080)	2.03† (1.29-3.19)	30.67 (21.14-44.50)
Polyester	48	0.158 (0.116-0.215)	6.60‡ (3.50-12.43)	41.85 (25.07-69.87)
Cotton	44	0.024 (0.018-0.031)	0.81†‡ (0.43-1.50)	31.87 (19.07-53.28)
Wool	18	0.111 (0.067-0.184)	6.84‡ (2.18-21.43)	61.69 (23.84-159.62)

*Mean (95% CI).

† $p < 0.05$.

‡ $p < 0.01$.

including those at the entrance and centrally in the room, had markedly higher Fel d 1 levels than non-carpeted (smooth) floors, whether measured as $\mu\text{g/gm}$ (2.21 $\mu\text{g/gm}$ [1.28 to 3.84] for carpet, 0.33 [0.10 to 1.14] for noncarpeted) or as $\mu\text{g/m}^2$ (3.62 $\mu\text{g/m}^2$ [1.73 to 7.53] for carpet, 0.015 [0.002 to 0.09] for noncarpeted). The two schools that kept cats were not the schools with the highest classroom levels and were included in the analysis.

There was a strong positive correlation ($r^2 = 0.93$) between classroom floor Fel d 1 and pupil cat ownership (Fig. 2), but the correlation between mean clothing Fel d 1 and mean floor Fel d 1 for each classroom did not reach statistical significance ($r^2 = 0.50$, $p = 0.14$). The results from two classrooms in which the participation rate of children was less than 50% were excluded from the correlation analysis.

No significant differences in Fel d 1 levels between schools could be explained on the basis of age, construction materials, ventilation, and heating systems.

DISCUSSION

Fel d 1 is widespread throughout the environment, being readily detectable in places where no cats are present. Our findings confirm extremely high cat ownership in New Zealand, as reported recently.³

Children from homes with cats carry significant amounts of allergen on their clothes (mean Fel d 1, 6.1 μg per garment), with wool and polyester garments containing greater amounts than cotton clothing. There may be differences in the frequency of laundering these garments because it is likely that woolen garments, which are more difficult to launder, are washed less frequently than cotton ones. Electrostatic charge differences between synthetic and wool carpet have been suggested as a cause of differences in Der p 1 airborne samples¹⁸ and could possibly contribute to the differences in Fel d 1 detected in our study. More puzzling is why girls' clothing has significantly higher levels of allergen than boys', even after controlling for cat ownership and fabric differences. Girls' garments also had

greater amounts of Der p 1 (mean, 3.6 $\mu\text{g/gm}$ [3.0 to 4.3]) than boys' (2.0 $\mu\text{g/gm}$ [1.7 to 2.5]).¹⁹ It is possible that girls spend more time indoors, therefore potentially with greater indoor allergen contact time. Additionally, girls' clothing may be laundered less frequently.

The observation that children whose cats were excluded from their bedroom showed lower levels of Fel d 1 on their clothing has useful implications in terms of reducing allergen transport. This is consistent with the finding that bedroom floor and bedding Fel d 1 is significantly reduced in this age group if the cat is kept out of the bedroom.¹²

Although mean Fel d 1 (3.6 $\mu\text{g/m}^2$ carpet and 0.013 $\mu\text{g/m}^2$ noncarpeted) in these classrooms of 7- to 9-year-old children were similar to those in cat-free homes in Wellington (1.65 $\mu\text{g/m}^2$)¹² and the United States,²⁰ six of 11 classrooms (55%) had a sample containing Fel d 1 at greater than 8 $\mu\text{g/m}^2$, the level suggested as the threshold for sensitization and symptom development.²¹

The Fel d 1 levels found in Wellington classrooms in this study are higher than those reported from the United Kingdom and Sweden (0.6 and 0.13 $\mu\text{g/gm}$, respectively, floor type not specified) but similar to those from Norway (carpeted, mean 3.28 $\mu\text{g/m}^2$; noncarpeted, 0.28).

All classrooms had a central carpeted area where children sit for a proportion of the day, and this site had significantly higher levels of Fel d 1 than the entrance to the classroom or uncarpeted areas if these were present. These results suggest that allergen shedding during the time spent on the carpet is a factor, as well, perhaps, as additional transport of allergen into the classroom on shoes and bags. Fel d 1 from the floor in the center of the room was positively correlated with pupil cat ownership and clothing Fel d 1. Together, these findings provide further evidence of the importance of carpets as allergen reservoirs and support the theory that cat allergen is transported into "cat-free" areas on clothing.

There is a growing belief that exposure to Fel d 1 is a community problem, supported by evidence that it is detectable in most public buildings and that significant allergen levels can be detected on clothing. Our findings that carpets have significantly higher levels of allergen than noncarpeted floors indicate that the introduction of carpets should be discouraged in schools. Our findings that some fabrics contain higher levels of allergen than others could be of considerable practical importance, and this knowledge could be used to minimize allergen transfer on clothing.

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