

Airborne cat allergen reduction in classrooms that use special school clothing or ban pet ownership

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Background: Allergens from furred animals are brought to school mainly via clothing of pet owners. Asthmatic children allergic to cat have more symptoms when attending a class with many cat owners, and some schools allocate specific resources to allergen avoidance measures.

Objective: The aim of the current study was to evaluate the effect of school clothing or pet owner-free classes compared with control classes on airborne cat allergen levels and to investigate attitudes and allergic symptoms among the children. **Methods:** Allergen measurements were performed prospectively in 2 classes with school clothing, 1 class of children who were not pet owners, and 3 control classes during a 6-week period in 2 consecutive years. Portable pumps and petri dishes were used for collection of airborne cat allergen, and a roller was used for sampling on children's clothes. Cat allergen (*Fel d 1*) was analyzed with enzyme-linked immunoassay and immunostaining. Both years, questionnaires were administered to the children.

Results: We found 4-fold to 6-fold lower airborne cat allergen levels in intervention classes compared with control classes. Levels of cat allergen were 3-fold higher on clothing of cat owners than of children without cats in control classes. Pet ownership ban seemed less accepted than school clothing as an intervention measure.

Conclusion: For the first time, it has been shown that levels of airborne cat allergen can be reduced by allergen avoidance measures at school by using school clothing or pet ownership ban, and that both measures are equally efficient. The clinical effect of these interventions remains to be evaluated. (*J Allergy Clin Immunol* 2004;113:1172-7.)

Key words: Cat allergen, allergen sampling, airborne, *Fel d 1*, intervention, school, petri dish, allergen avoidance, pump

Although no animals are allowed inside school buildings and day-care centers in Sweden and in many other countries, moderate levels of allergen from furred animals can be found in these premises.¹⁻⁴ Allergen is brought to school and other environments mainly via

Abbreviation used

Fel d 1: *Felis domesticus* major allergen 1

clothing of pet owners.^{4,5} There is a strong relationship between the number of cat owners among children in the class and measured cat allergen (*Fel d 1*) levels.^{4,6,7} Asthmatic children who are allergic to cat get more symptoms in classes with many cat owners when returning to school after summer holidays.⁸ This second-hand exposure to cat allergen may even contribute to allergic sensitization.^{9,10}

A recent position paper on how schools should deal with asthma and allergies states that substances that trigger allergic reactions should be kept at a minimum on school premises to avoid exacerbations of symptoms and increased intake of medicine in children with allergy and asthma.¹¹ It is crucial that proper recommendations for school staff are implemented to increase awareness of problems that these children have to face every day at school.

Because school attendance is mandatory and should offer good conditions for all children, some schools are allocating resources to allergen avoidance measures. This may include increased cleaning, removal of upholstery and curtains, and replacement of bookshelves with cupboards to minimize allergen load. We recently evaluated the effect of such combined measures, and we found no reduction of airborne cat allergen levels.¹² A previous cross-sectional study has shown that allergen levels in reservoir and airborne dust were lower in allergen-reduction day-care centers compared with conventional day-care centers.¹³ The allergen avoidance measures included smooth floors, nonsmoking staff, a perfume ban, and above all, a strict pet ownership ban among staff and children. However, it is difficult to find school classes or day-care centers in which no children have pets at home, although some do exist. Such classes have occasionally been established to make school attendance possible for a few children with severe asthma symptoms against pet allergens.

The basis for the current study was that we identified 3 children severely allergic to pets who had previously attended allergen-avoidance day-care centers and who could not be in their proposed school environment because of exacerbation of symptoms. They were under regular

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Supported by the Majblomman Foundation and the Konsul Th C Bergh Foundation.

Received for publication November 6, 2003; revised December 19, 2003; accepted for publication December 31, 2003.

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0091-6749/\$30.00

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doi:10.1016/j.jaci.2003.12.590

care by specialized pediatricians regarding medication and allergen avoidance advice. After repeated unsuccessful attempts to attend ordinary classes, 2 different solutions were implemented to facilitate school attendance for these 3 children: introducing special school clothing or a pet ownership ban, respectively. These measures resulted in such improved conditions for the children with allergy that they were able to attend school.

The aim of the current study was to evaluate the effect of the introduced intervention measures on airborne cat allergen compared with control classes from the same schools and to study differences between cat owners and children without cats within classes. Furthermore, the aim was to investigate allergic symptoms and attitudes toward intervention measures.

METHODS

Study design

The allergen sampling was performed during 6 school weeks during the spring term of 2002 in 6 classes, of which 3 had implemented allergen avoidance strategies before our study. After 1 year, the study was repeated at the same time of the year in the same classes (except 1 control class that was substituted) to investigate the consistency of the intervention over time. This study was approved by the Ethics Committee of the Karolinska Institutet.

Participating classes

The classes were situated in 3 different schools (1 intervention and 1 matching adjacent control class in each school) in 3 communities in the Dalecarlia province (Falun, Borlänge, and Sundbom), approximately 400 km northwest of Stockholm, Sweden. Children were between 6 and 12 years old, and all classes (except 1) had a high rate of cat owners (>20%). Two classes had implemented the use of school clothing 2 to 3 years before the current study: the children changed into special school clothes when arriving at school. The clothes used in this study had been purchased by the schools and were regular T-shirts, sweatshirts, and trousers, and thus were not similar to traditional school uniforms sometimes used in other countries. School and home clothes were kept separate in either 2-storage lockers or plastic bags hanging on opposite walls. Washing of clothes in a nearby laundry at school was performed depending on need, but socks were changed every day. Pet owners and children without pets changed clothes separately, and the symptomatic child used a separate entrance. No other children were allowed inside this part of the school, and all staff changed clothes before entering the classrooms. In the third class, a strict pet ownership ban among the children had been implemented 5 to 6 years before the study. Thus, keeping of furred pets or birds at home was not allowed. The parents had agreed to these arrangements before their children had enrolled first grade. Previously, an air cleaner (airflow 600 m³/h) had been placed in the pet ownership ban classroom (Elfi-600; ELFI Elektrofilter AB, Alingsås, Sweden). The following year, 1 control class declined participation in a second sampling period and was replaced by another equivalent control class. Age distribution and rate of cat ownership in classes each year are shown in Table I.

Sampling with petri dishes

Preparation of and sampling with petri dishes was performed as described previously.^{7,14} Briefly, 1 petri dish was placed with base and lid side by side facing upward on aluminium holders attached to

the wall. Sampling was performed during a normal 5-day school week, and dishes were replaced every week throughout the 6-week period and stored in plastic zip bags at room temperature until extraction of the collected dust, which was performed as described previously.⁷

Sampling with person-carried pumps

Sampling of inhalable dust using person-carried pumps was performed on 4 occasions during each 6-week period. Air sampling took place during 2 hours of whole-class morning lessons. Two pumps (Airchek 52 with Institute of Occupational Medicine sampling head; SKC, Eighty Four, Pa) with 25-mm-diameter polytetrafluoroethylene filters, 1-μm pore size (Millipore AB, Sundbyberg, Sweden), were carried by 2 children (cat owner and child without cat, respectively; n = 48). The Institute of Occupational Medicine sampling head was attached in the breathing zone. Airflow rate was adjusted to 2 L/min, and the total sampling time was recorded. Air filter cassettes were stored at -20°C until extraction.

Filters were thawed and extracted in 2 mL PBS, 0.1% Tween 20, 0.15% Kathon CG by rotating overnight at room temperature. Samples were stored at -20°C until analysis.

Sampling on tape with roller

Before each sampling occasion using person-carried pumps, samples were collected from the children's school clothing or, in the pet owner-free class only, personal clothing (cat owner and child without cat). A hand-held roller with adhesive tape (kind gift from Dr Euan Tovey, Woolcock Institute of Medical Research, Sydney, Australia) was once rolled back and forth on the clothing, just under the collarbone.⁵ Tape was removed, and a plastic cover protected the sticky surface until further analysis.

An area 4 cm² (1 cm wide and 4 cm long) was cut from the tape and extracted in 2 mL PBST_K rotating overnight at room temperature. Samples were then stored at -20°C until analysis.

Roller samples from the first year (n = 80) were used for detection of particles containing *Fel d 1* by using the HALOgen assay (Woolcock Institute of Medical Research, Sydney, Australia). Briefly, an area 1 cm² from the tape was laminated with a polyvinylidene difluoride protein-binding membrane, and allergen-bearing particles were immunostained and counted as described previously.¹⁵

Fel d 1 analysis

All petri dish samples were analyzed in a monoclonal sandwich enzyme-linked immunoassay as presented previously.⁷ Samples near or below the detection limit (0.156 ng/mL), air samples, and extracted roller samples were analyzed in an amplified enzyme-linked immunoassay (by using AMPAK signal amplification; Dakopatts, Älvsjö, Sweden) according to the manufacturer's recommendations. The standard curve range in the amplified assay was 2.5 to 160 pg *Fel d 1*/mL.

Rare samples with intra-assay coefficient of variation >10% were re-assayed. The *Fel d 1* monoclonal antibody kit including standard was purchased from Indoor Biotechnologies Ltd (Cardiff, United Kingdom).

Questionnaires

During each term, a questionnaire modelled on the International Study of Asthma and Allergies in Childhood¹⁶ format with additional questions about pet contacts and school and home environment was sent to the children. Parents were asked to complete the questionnaires with the children.

TABLE I. Number of children, cat ownership, and mean age in all classes each school term

Class	Spring 2002			Spring 2003		
	Children, n	Cat owners, n (%)	Mean age y (minimum-maximum)	Children, n	Cat owners, n (%)	Mean age y (minimum-maximum)
School clothing (class A)*	28	6 (21)	7 (6-9)	24	5 (21)	7 (6-9)
School clothing (class B)	24	8 (33)	7 (7-8)	24	10 (42)	8 (8-9)
Pet ownership ban (class C)	21	0 (0)	10 (10-11)	20	0 (0)	11 (11-12)
Control (to class A)*	25	7 (28)	7 (6-9)	21	4 (19)	7 (7-10)
Control (to class B)	19	6 (32)	9 (9-10)	21†	10 (48)†	7 (7-8)†
Control (to class C)	21	8 (38)	10 (10-11)	21	6 (29)	11 (11-12)

*Mixed ages.

†New class compared with spring 2002.

TABLE II. Geometric mean cat allergen (*Fel d 1*) levels in samples from intervention classes (including both school clothing and pet ownership ban), control classes, cat owners, and children without cats for each measurement period, respectively*

Sampling method	Measurement period			<i>F</i> value (<i>P</i> value), intervention vs control			<i>F</i> value (<i>P</i> value), cat owner vs child without cat
		Intervention	Control		Cat owner	Child without cat	
Petri dish pg/m ² /d	Spring 2002	5550 n = 18	25,600 n = 18	7.34 (.054)†	11,900‡ n = 36	—	—
	Spring 2003	4230 n = 18	37,300 n = 18	24.42 (.0078)†	12,600‡ n = 36	—	—
Pump pg/m ³	Spring 2002	255 n = 24	760 n = 24	9.81 (.0031)	811 n = 20	285 n = 28	8.65 (.0052)
	Spring 2003	218 n = 24	2230 n = 24	23.80 (<.0001)	1650 n = 20	377 n = 28	6.48 (.014)
Roller pg/cm ²	Spring 2002	13.8 n = 39	15.0 n = 42	0.0004 (.98)	31.3 n = 31	8.80 n = 49	13.35 (.0005)
	Spring 2003	21.0 n = 24	30.4 n = 24	0.199 (.66)	64.5 n = 20	12.9 n = 28	15.18 (.0003)
HALOs/cm ²	Spring 2002	5.2 n = 39	5.3 n = 41	0.001 (.98)	6.3 n = 31	4.7 n = 49	1.31 (.26)
	Spring 2003§	ND	ND	ND	ND	ND	ND

*Comparisons of cat allergen levels between intervention and control and between cat owner and child without cat using 1-factorial ANOVA.

†Repeated measures ANOVA.

‡Cat owner/child without cat grouping not applicable.

§HALOgen assay was not used for samples from spring 2003.

ND, No data.

Statistics

All data were analyzed by using Statview 5.0 software (SAS Institute, Cary, NC). Data from air and roller sampling were log-transformed and further analyzed using 1-factorial ANOVA. Because roller samples (analyzed with immunostaining) included zero values ($n = 12$), all absolute counts were added with 1 before log transformation.¹⁷ Samples below the detection limit in the amplified ELISA analysis were assigned a value of half of the detection limit ($n = 11$). Data from consecutive petri dish sampling were log-transformed and analyzed by using repeated-measures ANOVA. The repeating factor was *time* (6 measurement weeks, 2 measurement periods). The independent factor was *type of measure* with the levels *control* and *intervention* (including both school clothing and pet ownership ban). ANOVA analyses were performed for each term separately because 1 class was substituted. Because only left censoring was used, values below the detection limit were included in the analysis. Unpaired comparisons between children without cats and cat owners (both measurement periods combined) were made by using the Student *t* test. A *P* value $< .05$ was considered significant.

RESULTS

Cat allergen levels in classes with school clothing and pet ownership ban compared with control classes

Airborne cat allergen levels. Airborne cat allergen levels were on average 4-fold to 6-fold lower in classes with school clothing or a pet ownership ban compared with control classes. There was no significant interaction between groups in the ANOVA analyses (Fig 1, A and B; Table II).

Cat allergen levels on clothes. Allergen levels on clothes did not differ between intervention and control classes, but the difference between cat owners and children without cats was significant in control classes but not in classes with school clothing. The number of allergen-bearing particles measured with the HALOgen assay was not influenced by either type of class or cat ownership (Table II).

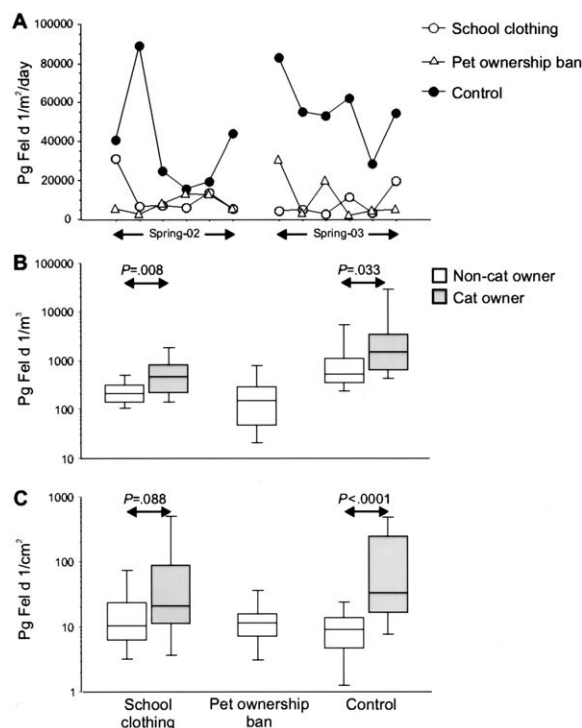


FIG 1. Cat allergen measured with weekly petri dishes (**A**), with person-carried pumps (**B**), and on clothing (**C**). In **A**, each data point is the mean level of 1 weekly petri in 2 classes (school clothing) and 3 classes (control). In **B** and **C**, box plots with medians are shown where a box corresponds to 25th to 75th percentiles and vertical lines correspond to 10th to 90th percentiles, respectively.

Questionnaires

After 1 to 2 reminders, the response rate was 86% (119/138) for spring 2002 and 92% (121/131) for spring 2003. Generally, the questionnaires were completed according to instructions.

In the 5 classes that participated both years, 28 children had left their classes and 18 new children had started since the first year. The rate of cat ownership was high (>19%) among children both years (Table I). Because ratings were very similar both years, results are given for the second year only.

Pet contacts. Almost 50% (excluding the pet owner-free class) had at least 1 furred pet at home, and cat was most common (28%). Regardless of type of class, more than every fourth family (26%) had actively avoided and/or gotten rid of furred animals because of allergy and/or asthma among family members. In families with a child with symptoms against furred animals, 88% had refrained from having pets, compared with 16% in families without a child with symptoms ($P<.0001$; Fisher exact test). Many children visited other homes with furred pets on a regular basis (71%).

School environment. Generally, children in school clothing classes were more satisfied with classroom temperature, air quality, and cleaning than children in the other classes. They also seemed to approve of the intervention more than their counterparts in the pet ownership ban class. Results of ratings from the second year are presented in Fig 2.

Symptoms. Generally, symptom ratings were higher in the pet ownership ban class, whereas ratings were similar in school clothing and control classes. Any symptoms (including asthma, eye/nose, and skin) against any allergen (including furred animals, pollen, and house dust mite) were reported by 11% to 42%, and any symptoms related to cat exposure were reported by 7% to 21%.

DISCUSSION

Airborne cat allergen levels, measured with petri dishes or person-carried pumps, were lower both in classes with school clothing and a pet ownership ban, compared with control classes. The measures appeared to be equally efficient in reducing cat allergen levels. To our knowledge, this is the first study that shows a reduction in airborne cat allergen levels after implementation of allergen avoidance measures in classrooms. School clothing or a pet ownership ban seem to be better allergen avoidance alternatives than just implementing dust reservoir elimination strategies.¹² An air cleaner was present in the pet ownership ban classroom, but it was not possible to evaluate the potential effect of this measure alone in the current study. However, the effect of air cleaners has been evaluated in several previous studies, mostly showing no or little effect on airborne allergen levels and very seldom significant clinical effects.¹⁸ Most air cleaners are intended for home use, and they are unlikely to be efficient in a large

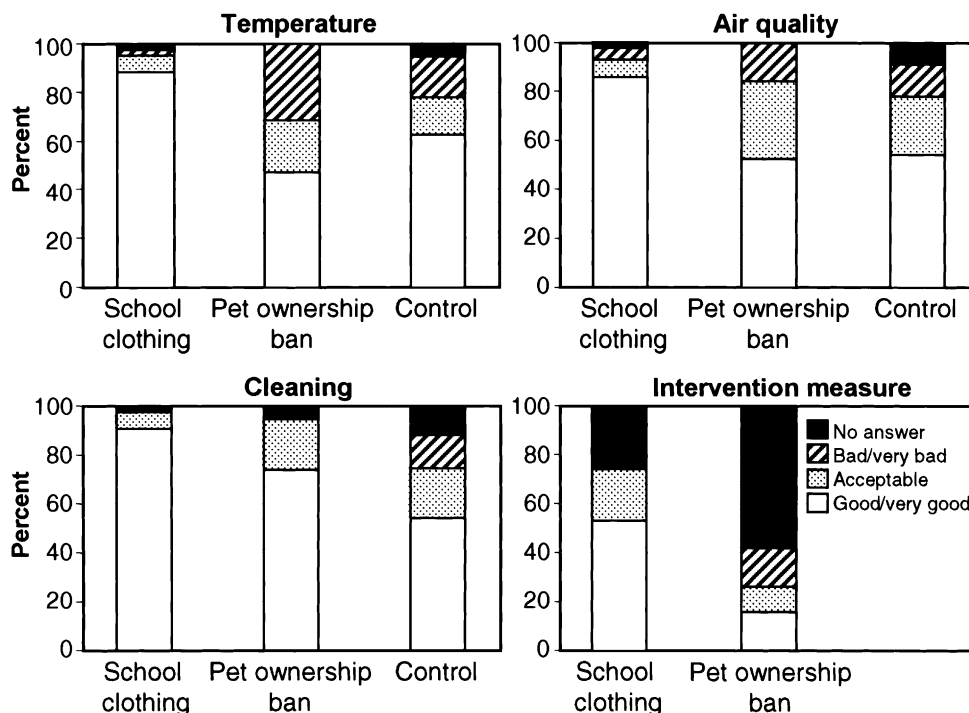


FIG 2. Opinions ("What is your child's opinion about the school environment regarding...") about temperature, air quality, cleaning, and, where applicable, intervention measures in school clothing, pet ownership ban, and control classes during spring 2003.

classroom with 25 or so children, often in combination with open windows and doors. It is therefore reasonable to assume that most allergen reduction was a result of the pet ownership ban.

A strength of the current study is the prospective design. We were interested in studying how the intervention implementation worked over time and confirming the previously observed differences by repeated sampling the following year. There was a greater variation in allergen levels within and between the 2 measurement periods in control classes than in intervention classes, in which levels were more constant. Unlike intervention classes, airborne levels were higher the second year in control classes, indicating that allergens accumulated over time and that the exposure situation was not as well controlled. One may argue that the observed differences and variations in allergen levels were caused by changes in the rate of cat owners from the first year to the next year. However, the overall change in cat ownership from 2002 to 2003 within control classes (33% to 32%) and intervention classes (27% to 32%) was marginal and could not influence allergen levels to such an extent. Most importantly, the numbers of cat owners remained high both years (according to inclusion criteria). There did not appear to be a deterioration of the achieved level of allergen reduction—rather, a slight deterioration in the control classes—and the previously observed differences between intervention and control classes remained.

Cat allergen levels measured in the breathing zone or on clothing of cat owners were higher compared with those

for children without cats, even in classes in which school clothing was used. This finding suggests that a child allergic to pets should not be seated close to pet owners even in an allergen-avoidance class. However, this observed difference in allergen levels on school clothing was more pronounced in control classes, suggesting that the clothing used only at school was less contaminated by cat allergen compared with clothing used at home as well as at school. However, there was no difference between control and intervention classes in contrast to air sampling. The roller sampling method is somewhat crude and less standardized compared with air sampling, and allergen contamination from hair, skin, and outdoor clothing can not be dismissed. These possible contamination sources may mask differences in allergen levels that can be observed by air sampling. Hence, roller sampling on clothes may not be used as a proxy for airborne allergen exposure.

The difference in airborne cat allergen levels between classes with or without allergen avoidance in the current study was of a similar magnitude as the difference seen between ordinary classes with many (>20%) and few cat owners.⁷ A study by Almqvist et al⁸ showed that cat-sensitized children with asthma had more symptoms when returning to school after the summer holidays if they attended classes with many cat owners. We therefore hypothesize that the magnitude of the difference in airborne cat allergen levels is of clinical relevance, although no clinical parameters were measured in the current study. Hence, the self-reported improvement of

symptoms among the 3 severely symptomatic children may be related to the lower allergen levels, although psychological influence must also be considered.

There was a difference in attitude, and the children and parents in the school clothing classes were generally more satisfied with the implemented measure than those in the pet ownership ban class. The general dissatisfaction with the pet ban may influence the perception of other factors. Interference with persons' living conditions such as introducing a long-term pet ban appears to be a problem after a while when persons may think of it as a great sacrifice instead of a consideration for a schoolmate with allergy. The alternative, using school clothing, has also been proposed to be positive for other reasons. It is cheaper for the families, and the influence of fashion becomes less important among the children. Compliance regarding implementation of intervention measures is important among families as well as school personnel and management. In the current study, the cooperation between medical and school personnel was good in all 3 schools.

The rate of reported allergic symptoms was somewhat higher in the pet ownership ban class. This may be a result of a selection factor, because this class had been established for almost 6 years and therefore might naturally have attracted children wanting a pet ownership ban because of symptoms against pets. The school clothing classes had been established for only 2 to 3 years, and no selection had occurred at this point. However, it is difficult to interpret any observed differences between the groups because of age distribution differences and small numbers. In the current prospective study, it was not possible to study the incidence of allergic symptoms. There were too few children, and 1 year might not have been enough follow-up time. Any possible changes over time might have been caused by either a turnover of children or a change in age.

A surprisingly high proportion, almost 30% of all families regardless of type of school class, reported that they had refrained from acquiring or had gotten rid of pets because of an allergic family member. Several studies are now reporting that furred pets during childhood may have a protective effect against allergy development.^{19,20} Because information about pet ownership is rather crude in these and similar studies ("current," "previous," and "not ever" pet ownership), there may be a potential selection bias to consider in light of the questionnaire data in the current study.

In conclusion, school clothing and a pet ownership ban are equally efficient in reducing airborne cat allergen levels in classrooms, and these intervention measures separately lower the allergen levels 4-fold to 6-fold. This difference is similar to what has been observed between classes with many and few cat owners and has also been shown to be clinically relevant.⁸ The current study is small, and it was not possible to analyze clinical parameters in this setting because the intervention measures had already been in use for several years. However, it seems obvious that the implementation of intervention measures has improved the school environment and enabled school

attendance for the 3 symptomatic children in the current study.

We thank the participating children, schools, and teachers.

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