

Relevance of allergens from cats and dogs to asthma in the northernmost province of Sweden: Schools as a major site of exposure

Matthew S. Perzanowski, BA,^a Eva Rönmark, SRN,^{b,c} Brian Nold, BA,^a Bo Lund-bäck, MD, PhD,^{b,c} and Thomas A. E. Platts-Mills, MD, PhD^a Charlottesville, Va, and Stockholm, Umeå, and Luleå-Boden, Sweden

Background: The prevalence of asthma in the northernmost region of Sweden has been estimated at 6% to 8% in spite of the very dry climate. The causes of the increase in asthma are not clear, but conditions are unfavorable for dust mite growth, and domestic animals are thought to be the primary source of indoor allergens.

Objectives: We sought to investigate the relationship between asthma, exposure, and sensitization in Northern Sweden, with a focus on the role of schools.

Methods: Serum was collected from 110 asthmatic children, 55 children with symptoms of asthma but no established diagnosis, and 63 control children (age, 7 and 8 years). Total IgE and specific IgE to 7 allergens were measured. Dust samples were collected from the classrooms of 7- and 8-year-old children in 22 schools from Kiruna and Luleå, Sweden. For comparison, dust was also collected from 24 homes in Kiruna and 2 schools in Virginia in the United States.

Results: Serum IgE antibody assays on 165 children with respiratory symptoms confirmed that there was a high degree of sensitization to cat, dog, and birch in Northern Sweden. Cat and dog allergens were present in almost all of the school samples in Sweden. By contrast, dust mite and cockroach allergens were generally unmeasurable. The highest levels of cat and dog allergens were found in samples from desks and chairs. Cat and dog allergen levels in the schools were comparable with but higher than those in the homes without pets. The schools in Virginia had similar allergen levels, except that samples from this humid region also had significant mite allergen.

Conclusions: In this climate the primary sensitization associated with asthma is to cat dander and dog dander but also to birch pollen. Mite and cockroach allergens were not present in the dust samples, and sensitization to these allergens was not significant. The schools appear to be a major site of exposure to cat and dog allergens. These results are relevant both to an

understanding of the reasons for the increase in asthma in this region and to any proposal to reduce exposure to allergens. (*J Allergy Clin Immunol* 1999;103:1018-24.)

Key words: Asthma, children, cat allergen, dog allergen, school

Located at the polar circle, Norrbotten is the northernmost region of Sweden. In keeping with the cold climate, the humidity in this region is very low. Nonetheless, the prevalence of asthma in this area has been rising and has recently been estimated at 6% to 8%.^{1,2} Increases in the number of children and young adults who receive treatment for asthma have been reported from many parts of the world, including Scandinavia and other areas with a dry climate.³⁻⁸ Many studies aimed at elucidating the cause of the increase in asthma prevalence have focused on the indoor environment.⁷⁻¹⁰ In a detailed population survey in Norrbotten involving 3525 children (ages, 7 and 8 years), cat and dog allergens elicited the greatest number of positive skin test responses.² A comparable pattern of sensitization has been reported in other areas of the world where the climate is too dry for dust mite survival because of altitude.⁷ By contrast, the group in Linköping have found mite allergen in Swedish houses and have suggested that concentrations of mite allergen below 2 µg/g can be relevant to sensitization.¹¹

Studies over the last 10 years have demonstrated the presence of animal allergens in public buildings.¹²⁻¹⁴ These findings suggest that significant exposure to indoor allergens might occur outside the home. Several reports have focused on cat and dog allergens in schools, but studies from Norway offered varying results. In 1994, Fel d 1, the major cat allergen, was found to be present at higher concentrations in the schools than in the homes of children who did not have any cats, although no school sample had greater than 1.5 µg/g Fel d 1.¹⁵ Another Norwegian group in 1997 published an article indicating that the school dust was relatively allergen free.¹⁶ By contrast, a report from Southern Sweden found quantities of both cat and dog allergens in the schools that were high enough to be the cause of symptoms.¹⁷ Recently, Sarpong et al¹⁸ in Baltimore have shown the presence of significant concentrations of cockroach allergen in city schools.

In this study we have evaluated both serum IgE antibodies and exposure to indoor allergens of children in Norrbotten to investigate the relationship between asthma

From ^athe University of Virginia Asthma and Allergic Diseases Center, Charlottesville; ^bthe Respiratory Epidemiology Unit, Department of Occupational Medicine, National Institute for Working Life, Stockholm and Umeå; and ^cThe OLIN Study Group, Department of Medicine, Central Hospital of Norrbotten, Luleå-Boden.

Supported by National Institutes of Health grants AI-20565, AI-34607, and the Swedish Asthma-Allergy Foundation.

Received for publication Nov 20, 1998; revised Jan 22, 1999; accepted for publication Feb 15, 1999.

Reprint requests: Thomas A. E. Platts-Mills, MD, PhD, UVa Asthma and Allergic Disease Center, Box 225, Health Science Center, Charlottesville, VA 22908.

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0091-6749/99 \$8.00 + 0 1/1/97965

ma, exposure, and sensitization. The results confirm that cat and dog (but not mite or cockroach) allergens are associated with asthma. The results demonstrate high levels of cat and dog allergens both in houses and schools; however, we were unable to detect mite allergen in any of the dust samples from Norrbotten.

METHODS

Study populations

The children studied here were participants in a longitudinal study of all the students from the 3 municipalities of Kiruna, Luleå, and Piteå who were enrolled in grades 1 and 2 (ages, 7 and 8 years) in 1996. Of the children invited, 3431 (97%) participated in the study.² The schools investigated were those in Kiruna and Luleå. Located inland, Kiruna is a 20,000 square kilometer town of 26,000 inhabitants (as of 1996) 200 km north of the Arctic Circle (latitude, 68° north). The average yearly temperature is -2°C (January, -15°C; July, 12°C). Dust was collected from 16 schools in Kiruna. Luleå is a city of 71,000 inhabitants (as of 1996) located south of the Arctic Circle on the Baltic Sea (latitude, 66° north). The average temperature in Luleå is 2°C (January, -11°C; July, 15°C). Dust was collected from 6 schools in Luleå. In both locations the relative humidity varies considerably between summer and winter; however, in keeping with the average temperatures, the absolute humidity is very low. Schools were selected from urban and rural areas of each municipality.

To assess the sensitization profile of the children in this cohort, serum was collected from 228 children (110 children with asthma, 55 symptomatic children, and 63 randomly selected control subjects) for the measurement of both specific and total IgE, as well as IgG to Fel d 1. One third of the serum samples were from each of the cities, Kiruna, Luleå, and Piteå. Piteå is a coastal city about 50 km south of Luleå with a similar climate. Children were classified as asthmatic if they had been diagnosed as such by a physician or had been prescribed asthma medication in the last year. Symptomatic subjects were defined as those not in the asthma group whose parents reported that the child had, in the last 12 months, either been woken at night by wheezing or their chest had sounded wheezy without the child having a cold. The control subjects had no complaint of asthma symptoms. Skin testing by lancet was performed on 185 of these children. Surveys, which included questions about the past or current presence of an animal in the home, were available from the parents of 185 of these children.

To compare levels of allergens in the schools in Northern Sweden to those in homes, 24 of the children from the study living in Kiruna were randomly selected for a home visit. Dust was collected from the homes of both asthmatic (n = 16) and nonasthmatic subjects (n = 8) and homes with and without pets. The children whose houses were visited had been skin tested; however, serum was not collected from them.

As a control, 2 schools were studied in Virginia in the United States. The 2 schools are located in Charlottesville and Albemarle, the county that surrounds Charlottesville. Both schools were the focus of a study that has been recently published, and therefore the sensitization and levels of allergen in houses of these children were known.¹⁹ Geographically located at 38° north, these schools are in a temperate climate, with an average temperature of 14°C (January, 1°C; July, 25°C) and relative humidity that is conducive to significant dust mite growth.

Dust samples

Dust samples were collected with a hand-held vacuum cleaner with an attached dust trap (Fussnecker, Springfield, Ohio).²⁰ In the schools separate samples were collected from the classroom floor,

the desk and chair level, the corridor outside of the classroom, the gym, and the gym changing room. In the homes samples were taken from the kitchen, the living room floor, the living room sofa, the child's bedroom floor, and the child's bedding. Dust was collected until a sufficient sample was obtained. Standardization between collections was maintained as in previous studies by reporting the dust samples as a concentration of allergen per gram of dust.⁹ Samples were sieved, and 100 mg was extracted in 2 mL of borate-buffered saline overnight at 4°C. After centrifugation, the supernatant was removed and stored at -20°C until being assayed. Extracts were assayed by 2-site mAb-based ELISA assay for dust mite (Der p 1 and Der f 1), cat (Fel d 1), dog (Can f 1), and cockroach (Bla g 2) allergens.²¹⁻²³

Serum assay

For the evaluation of specific and total IgE, the ImmunoCAP system was used (Pharmacia Upjohn, Uppsala, Sweden). With this assay for specific IgE, allergens are prebound to a cellulose sponge-like matrix. Serum samples are incubated in the sponge, washed, and then incubated with an antibody to IgE, which is detected by fluorescence. Total IgE is measured in the same manner, except that an anti-IgE antibody is bound to the sponge. IgE specific to *Dermatophagoides pteronyssinus*, cat epithelium, dog, *Alternaria* spp, *Aspergillus* spp, cockroach, and birch were measured. In addition IgG against Fel d 1 was measured by an antigen-binding assay (RIA) by using radiolabeled Fel d 1 (kindly provided by Dr Martin Chapman, University of Virginia, Charlottesville, Va) incubated with the children's serum. A goat anti-human IgG was used to precipitate the IgG. Counts were measured in a gamma counter.

Statistical methods

For all averages and statistical analyses in this article, results below detectable assay limits were assigned a value of the lower limit. Because of logarithmic distribution of the data, geometric means were used. The Mann-Whitney *U* test was used to compare allergen concentrations in homes with those found in schools, allergens in schools in Sweden with those in Virginia, and total IgE concentrations in the 3 groups. Chi-square test for trend was used to evaluate differences in sensitization among the 3 asthma classification groups. Regression analysis was used to compare concentrations of IgE to cat allergen with concentrations of IgG to Fel d 1.

RESULTS

Serum IgE antibody assays confirmed that there was a high degree of sensitization to cat, dog, and birch allergens in Northern Sweden (Table I). In contrast, sensitization to dust mite, cockroach, *Alternaria* spp, and *Aspergillus* spp was much less common. There was a significant association with asthma for sensitization to animal dander and birch allergens. Among this cohort, the presence of a cat at home has not been found to be a risk factor for either asthma or positive skin test responses to cat allergen.²⁴ In keeping with that finding, only 17% of the children with IgE antibodies to cat had a cat at home at some time. By comparison, 36% of the children without IgE antibody had a cat at home. To investigate further the significance of cat exposure, we measured IgG antibodies to the major cat allergen Fel d 1 by using an antigen-binding assay. In the whole group the presence of IgG antibodies was not significantly associated with asthma (Table I). Among those children who had IgE antibodies to cat allergen, there was an excellent correla-

TABLE I. Percentage of sera from asthmatic, symptomatic, and control children from Northern Sweden with at least 0.7 IU of IgE antibody per milliliter

Specific IgE	Control children (n = 63)	Symptomatic children* (n = 55)	Asthmatic children (n = 110)†	P values‡
<i>D pteronyssinus</i>	0	3.6	2.7	.7
Cat epithelium	3.2	13	30	<.001
Dog	4.8	7	15	<.02
<i>Alternaria</i> spp	1.6	1.8	3.6	.4
Cockroach	3.2	1.8	3.6	.4
Birch	1.6	13	25	<.001
<i>Aspergillus</i> spp	0	0	8	<.01
Any allergen	11	23	43	<.0001
IgG to Fel d 1§	39	31	43	NS
Total IgE				
>40 IU/mL (%)	34	47	58	
>200 IU/mL (%)	11	11	26	
Geometric mean (IU/mL)	26.3	34.6	58.2	+

Serum IgE antibodies were measured by CAP. Pharmacia CAP class 2 and greater corresponds to at least 0.7 IU of IgE/mL.

+, There was a significant difference in total IgE ($P < .01$ as determined by Mann-Whitney U test) between the asthmatic and the control subjects and the asthmatic and nonasthmatic subjects (control and symptomatic subjects combined).

*Children not in the asthmatic group were classified as symptomatic if their parents reported that the child had, in the last 12 months, either been woken at night by cough or had wheezed without having a cold.

†Children were classified as asthmatic if they had been diagnosed as such by a physician or had been prescribed asthma medication in the last year.

‡Statistical significance determined by chi-square test for trend.

§Percentage of children with at least 125 U/mL IgG to Fel d 1.

tion between this measurement and IgG to Fel d 1 (Fig 1). However, there were 53 children whose sera had measurable IgG antibodies but no IgE (Fig 1). The presence of a cat at home was associated with IgG antibody to Fel d 1. Out of the 133 children with no IgG to Fel d 1, 26% had a cat, whereas 57% of the children who had detectable IgG to Fel d 1 had a cat in the home. Of the 28 children who had IgG to Fel d 1 and no IgE to cat allergen, 71% had a history of a cat in the home.

Analysis of the dust collected from schools demonstrated that cat and dog allergens were present in almost all samples and was often present in very high concentrations (Table II). By contrast, cockroach and dust mite allergens were generally unmeasurable. Indeed, no dust mite allergen was detected in any of the locations in the schools. Minimal cockroach allergen was detected in 5 of the 176 samples from schools, with none of the samples having greater than 1 μg of Bla g 2/g of dust. In the schools moderate levels of cat (1 to 8 $\mu\text{g}/\text{g}$) and dog (1 to 10 $\mu\text{g}/\text{g}$) allergen were found in 35% and 32% of the samples, respectively. High concentrations of cat allergen (>8 $\mu\text{g}/\text{g}$) were found in 7% of the school samples, whereas 30% had greater than 10 $\mu\text{g}/\text{g}$ dog allergen. Allergen levels were highest in the desks and chairs of each classroom, with 97% of these samples having at least moderate levels of dog allergen, and 82% of them having at least moderate levels of cat allergen (Fig 2).

The allergen levels in homes that did not contain a pet in Northern Sweden were similar to but lower than levels found in the schools (Table II). The concentrations of cat and dog allergens in the houses with pets were as much as 40-fold higher than those found in homes without a pet. As with the schools, there was no detectable dust

mite allergen in any of the samples tested. Cockroach allergen was only found in 1 home, and the levels were low. Fel d 1 concentrations in the schools were higher than in homes in which there was no cat ($P = .002$). The same analysis for Can f 1 did not show a significant difference between schools and homes without a dog ($P = .098$). The locations with the highest cat and dog allergens in the homes of non-pet owners were the sofa or the living room sample. These concentrations of allergen were significantly lower than the sites in the schools containing the highest amount of allergen (ie, the desk and chair sample) (Table II). The results show that the majority of the children in this study were exposed to cat and dog allergen in their school. Separation of the schools into urban and rural categories did not reveal major differences between the 2 groups.

The samples obtained from the 2 schools in central Virginia also contained significant cat and dog allergens. There was no difference between the city school (Charlottesville) and the school 14 miles west of the city (Albemarle). However, the profile was different from that in Northern Sweden in several ways (Table III). Mean cat allergen was higher in Virginia than in Sweden (geometric means, 2.3 $\mu\text{g}/\text{g}$ vs 0.76 $\mu\text{g}/\text{g}$; $P < .001$). Dog allergen, on the other hand, was higher in Northern Sweden than in Virginia (geometric means, 3.3 $\mu\text{g}/\text{g}$ vs 1.7 $\mu\text{g}/\text{g}$; $P = .036$). There was no detectable cockroach allergen in any of the school samples from Virginia. In contrast to Northern Sweden, there were moderate concentrations of dust mite allergens in many of the samples from the schools in Virginia. Carpeting in these classrooms consisted of partial floor rugs and individual mats. The highest levels of mite allergen were consistently found in desk and chair samples.

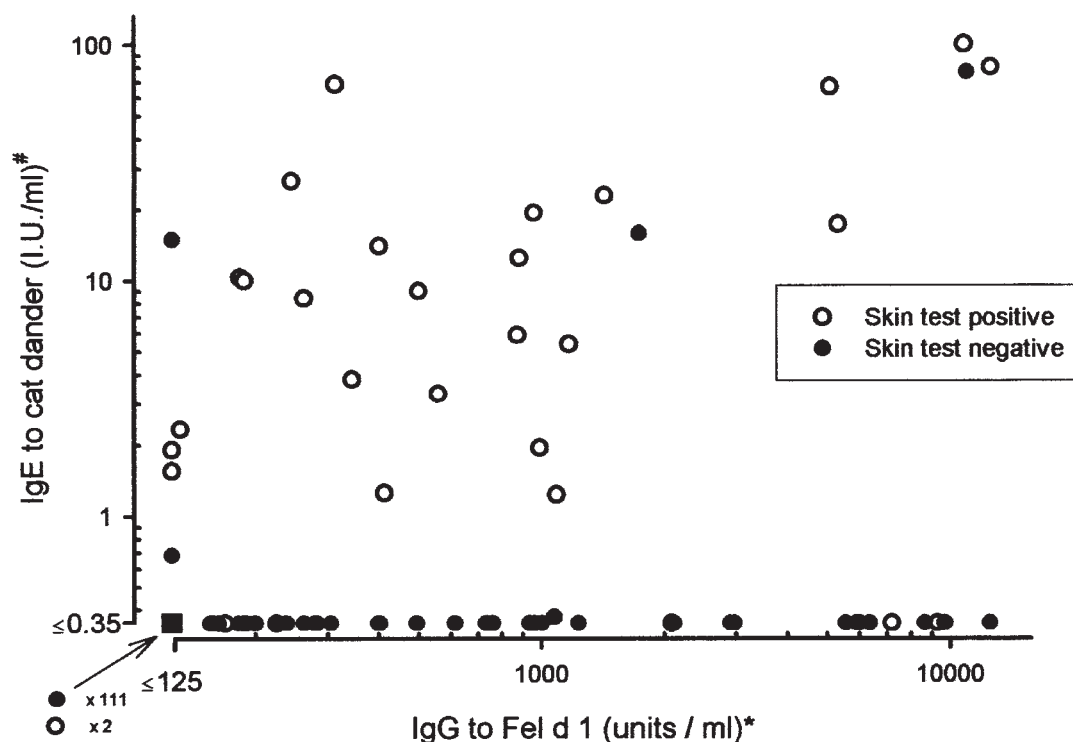


FIG 1. Values for IgG antibody to Fel d 1 measured by antigen-binding RIA (U/mL) are compared with IgE antibodies to cat dander measured by CAP (IU/mL). Values are shown for 31 subjects with positive skin test responses (*open circles*) and 152 subjects with negative skin test responses (*filled circles*). Among the sera with positive IgE antibodies, the correlation between IgG and IgE antibodies was highly significant ($r = 0.55$, $P = .002$). By contrast, the correlation between IgG and IgE antibodies among all the samples with some measurable antibody was not significant ($r = 0.14$, $P > .05$). One hundred thirteen sera had no detectable antibody to cat allergen, including 2 children with positive skin test responses (*filled squares*).

TABLE II. Concentration of allergens in dust samples from schools and homes in Northern Sweden

Dust samples	Fel d 1 ($\mu\text{g/g}$)	Can f 1 ($\mu\text{g/g}$)	Bla g 2 ($\mu\text{g/g}$)	Group 1 dust mite ($\mu\text{g/g}$)
All school samples (n = 176)	0.76 (<0.1-13)	3.3 (<0.5-176)	0.20 (<0.2-0.56)	<0.4
Desks and chairs (n = 64)	2.6 (<0.2-13)	15 (0.45-176)	0.20 (<0.2-0.56)	<0.4
Floors (n = 64)	0.31 (<0.2-8.8)	1.1 (<0.5-60)	0.20 (<0.2-0.25)	<0.4
Corridors (n = 21)	0.47 (<0.2-12)	1.0 (<0.5-28)	<0.2	<0.4
Changing rooms (n = 13)	0.49 (<0.2-4.6)	2.9 (<0.5-27)	<0.2	<0.4
Gyms (n = 14)	0.55 (<0.2-2.1)	3.0 (<0.5-25)	0.21 (<0.2-0.28)	<0.4
Homes with no pet (n = 74)*	0.42 (<0.2-9.4)	2.0 (<0.5-22)	<0.2	<0.4
Homes with a cat (n = 9)	33 (1.8-950)	1.5 (<0.5-4.1)	<0.2	<0.4
Homes with a dog (n = 29)	0.39 (<0.2-4.9)	79 (13-625)	0.27 (<0.2-1.3)	<0.4
Highest allergen in homes with no pet (n = 15)†	0.85 (<0.2-8.5)	5.4 (1.2-22)	<0.2	<0.4

Values shown are geometric means, with range of values in parentheses.

*Separate dust samples were collected from the living room, kitchen, sofa, bedroom floor, and bed of each house. There were 16 houses without a cat or dog, 2 with a cat, 6 with a dog, and none with both.

†The mean of the highest allergen samples in each home without a pet. In 8 homes the highest allergen concentration was found either in the sofa or the living room sample.

DISCUSSION

The assays for serum IgE reported here have confirmed that the symptomatic children in Norrbotten were primarily sensitized to cat, dog, and birch allergens. The

complete absence of dust mite allergen in schools and houses is in keeping with the results for sensitization and presumably reflects the very low humidity. As expected from visual reports, very little cockroach allergen was detected, and IgE antibodies to *Blattella germanica* were

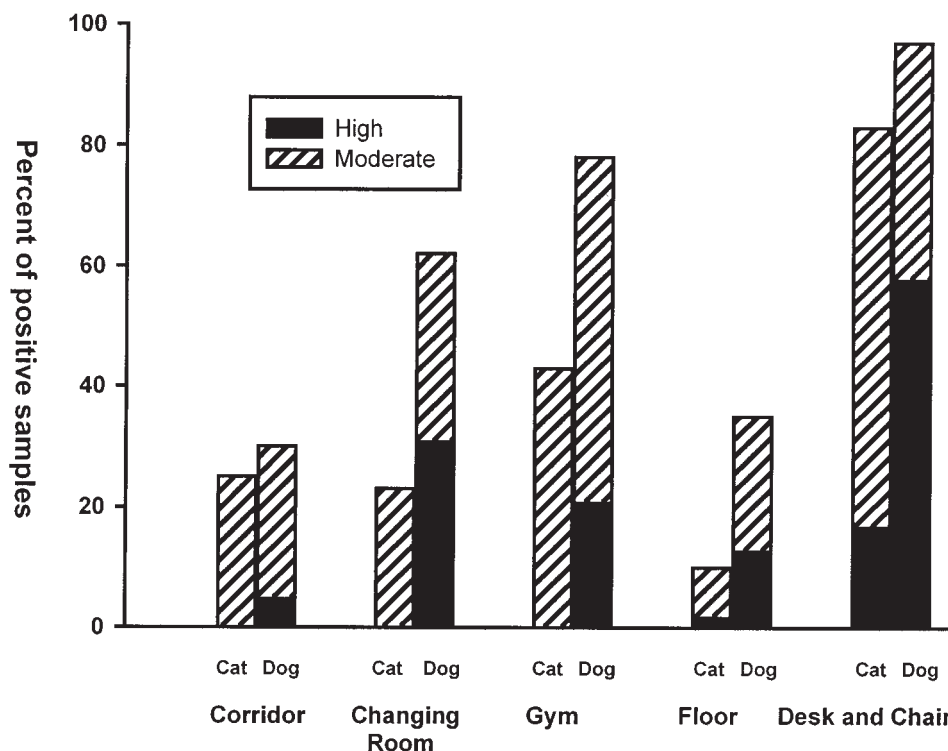


FIG 2. Percentage of samples from different locations in the Swedish schools containing allergen from a cat or dog. Dust samples with greater than 1 μg of Fel d 1/g dust or greater than 1 μg of Can f 1/g dust were considered to have moderate levels of cat and dog allergen, respectively. Dust samples with greater than 8 $\mu\text{g}/\text{g}$ Fel d 1 or greater than 10 $\mu\text{g}/\text{g}$ Can f 1 were regarded as high levels of exposure.

TABLE III. Concentration of allergens in dust samples from schools in Virginia

Dust samples	Fel d 1 ($\mu\text{g}/\text{g}$)	Can f 1 ($\mu\text{g}/\text{g}$)	Bla g 2 ($\mu\text{g}/\text{g}$)	Group 1 dust mite ($\mu\text{g}/\text{g}$)
Albemarle, Va				
Combined (n = 20)	2.7 (<0.4-90)	1.4 (<0.5-7.9)	<0.2	0.94 (<0.2-18)
Desks and chairs (n = 9)	11.3 (0.1-90)	1.7 (0.6-7.9)	<0.2	2.0 (<0.4-19)
Floors (n = 9)	0.87 (<0.2-2.9)	1.2 (<0.5-4.8)	<0.2	0.55 (<0.4-1.7)
Corridors (n = 2)	0.69 (<0.2-2.4)	1.3 (<0.5-3.2)	<0.2	<0.4
Charlottesville, Va				
Combined (n = 20)	2.3 (<0.4-185)	1.7 (<0.5-37)	<0.2	1.3 (<0.2-7.9)
Desks and chairs (n = 9)	4.8 (<0.4-185)	2.3 (<0.5-37)	<0.2	2.4 (1.0-8.4)
Floors (n = 9)	1.5 (1-4.4)	1.4 (<0.5-9.9)	<0.2	0.84 (<0.4-2.4)
Corridors (n = 2)	0.51 (<0.4-1.3)	0.97 (<0.5-1.9)	<0.2	<0.4

Geometric means of the allergen concentrations are listed, with the range of values in parentheses.

present in only 3% of the sera. The negative results for *Alternaria* spp are in contrast to results from other areas of the world but in keeping with skin test results in Sweden.^{2,25-27} In this population asthma is increasing similarly to the reported increases in Southern Sweden¹ and in more temperate regions of the world.³ The results provide further evidence that progressive increases in asthma have occurred in geographic areas where dust mites are not relevant.

The values reported here for cat allergen in the schools were similar to values previously reported for houses without a cat and higher than the concentrations found in

the 24 houses studied here. For dog allergen, the geometric mean value of 3.3 μg Can f 1/g of dust in the schools was significantly higher than that for cat allergen. Perhaps more striking, over half the classrooms had at least 1 dust sample with greater than 10 μg Can f 1/g of dust. The allergen concentrations found in homes in Northern Sweden were similar to values reported from Los Alamos, New Mexico, where the climate is dry because of the altitude, and animals are generally kept indoors.^{7,21} The results confirm that exposure can occur in homes without an animal. However, because many of the homes studied had animal allergen levels of less than

1 µg/g, it is clear that for a significant proportion of the sensitized children the highest exposure to animal allergen was at school.

The results in the schools in Virginia were striking because of the very high levels of cat allergen, the complete absence of cockroach allergen, and the presence of significant mite allergen. Among children attending these schools, sensitization to mite, cat, and cockroach allergens were each significantly associated with asthma, and mite sensitization was the strongest independent risk factor.¹⁹ In central Virginia 80% of the children were exposed to greater than 2 µg/g dust mite allergen at home. The comparable figures for cat and cockroach were 40% and 17%, respectively. The presence of cat allergen in the homes was reflected in the school samples, but the same was not true for cockroach allergens. Because there were no cats or dogs in any of the schools studied, the allergen must have been passively transferred into the schools, and it is not surprising that the highest levels of animal allergen were found in the places where children and staff sit. Cockroach allergen behaves aerodynamically as if it is carried on large particles.^{28,29} It has not been shown to stick to walls and clothing. The present data suggest that cockroach allergen is not transferred easily because even though approximately one third of the houses in Charlottesville had greater than 1 µg Bla g 2/g dust, no allergen could be detected in the dust from the Charlottesville school. Given these results, it is likely that the cockroach allergen previously reported in Baltimore schools¹⁸ was derived from insects in the schools rather than allergen transferred from homes. Elucidating the origin of the mite allergen found in the Virginia schools is more difficult. Dust mite allergen is carried on larger particles³⁰ and has not been found adhering to surfaces. Because most of the Virginia classrooms had either upholstered furniture or carpets, the source of the allergen was probably mites living in the schools.

Comparing these two areas, it appears that the schools may play very different roles. In Virginia it is unlikely that the schools are the primary site of sensitization or exposure to the dominant local allergen (ie, dust mites) because almost all of the children's houses had higher concentrations than the schools.¹⁹ By contrast, in Northern Sweden, where most of the children who are allergic to cats do not have animals at home and IgE antibodies do not correlate with the presence of a pet, for many of the children the school must represent the most important site of persistent exposure.

Whether exposure to allergen in the schools is related to primary sensitization would be difficult to establish. The results raise serious questions about the feasibility of allergen avoidance for animal dander. Removal of the pet combined with cleaning can dramatically reduce allergen exposure in the home. Airborne cat allergen can also be decreased by air filtration, removing reservoirs, and washing the cat (or dog).³¹⁻³⁶ The current results make it clear that proposals to control exposure to animal dander need to consider the schools and that this is especially true for allergic children who do not have an animal at home.

We thank the staff and school boards in Kiruna and Luleå, Sweden, and Charlottesville and Albemarle County, Virginia; Lena Gustafsson and Kerstin Kemi-Björnström for their assistance with dust collection; and Pharmacia for providing CAP reagents.

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