

Short communication

Dog allergen in indoor air and dust during dog shows

Background and methods: Dog dander is one of the most important indoor allergens in Nordic countries. Due to the population flow into cities, the number of dogs in urban areas has increased. Dog allergens can be found practically everywhere indoors. We measured allergen content in indoor air and dust during dog shows.

Results: In facilities used for dog shows, the dog allergen content was exceptionally high, up to 2 100 000 ng Can f 1/g dust, but it can be reduced by proper cleaning. The efficiency of cleaning will remain poor if furniture and textiles are not cleaned or the distribution of airborne allergen cannot be prevented.

Conclusions: Dog shows should not be held in public facilities, such as schools, where a significant proportion of occupants are hypersensitive to dog allergens and may therefore suffer symptoms due to the exposure to dog dander.

H. Mussalo-Rauhamaa^{1,2},
K. Reijula³, M. Malmberg¹,
S. Mäkinen-Kiljunen¹,
T. Lapinlampi⁴

¹Departments of Dermatology and Allergic Diseases, Helsinki University Central Hospital, Helsinki;

²Department of Public Health, University of Helsinki, Helsinki; ³Uusimaa Regional Institute of Occupational Health, Helsinki; ⁴Oulu Regional Institute of Occupational Health, Oulu, Finland

Dr Helena Mussalo-Rauhamaa
Departments of Dermatology and Allergic Diseases
Clinic for Indoor Air Health Problems
Helsinki University Central Hospital
Meilahdentie 2
FIN-00250 Helsinki
Finland

Accepted for publication 17 April 2001

Pet danders are important allergens in Nordic countries (1, 2). Sensitization to dogs and cats may develop within a few years (3). According to skin tests and IgE-antibody measurements, 15% of Finnish adolescents are sensitized to dogs (4, 5). There are over 700 000 dogs in Finland, and the number has increased by 100 000 over the last 20 years. In Sweden, the number of registered dogs increased by 500% between 1940 and 1980 (6).

Over 20 antigens have been isolated from dog-dander extract, seven of which are of allergenic importance (7). The most important allergen is *Canis familiaris* 1 (Can f 1), and dog dander and saliva have a high allergen content (8, 9).

Dog dander is transferred to the surrounding environment, including clothes. The levels of dog allergen in houses with dogs have usually been over 10 000 ng Can f 1 allergen/g dust (10, 11). Levels in homes without dogs are generally 10–100 times lower. The highest concentration of dog allergen appears on the living-room floor, on furniture, and in bedrooms.

Occasionally, high dog allergen levels can be found in households without a pet if the former occupants of the same household have had a pet, or if dogs often visit the building (12).

In Swedish day-care centers, dog allergen levels have usually been lower than in schools. In schools, the allergen levels ranged from 1700 ng to 28 200 ng (Can f 1)/g dust on the chairs and 56–506 ng/g on floors (13). Lower levels in day-care centres have been explained by the fact that their floors are cleaned daily by wet sweeping. Approximately 20% of airborne Can f 1 is carried on small particles that may remain airborne for long periods of time, unlike dust-mite allergen, more of that is carried on larger particles which fall rapidly to the ground after disturbance (14).

Dog shows have become popular, and their organizers have tried to find suitable places for exhibitions. They tend to be held in large public places not designed for this purpose, and sensitized asthma patients may use these facilities immediately

after a dog show. Some shows have even been held in schools. In order to measure the amount of dog allergen in indoor air during the dog shows, and to assess the effects of cleaning procedures on the allergen concentration in dust samples and in indoor air, the following experiments were carried out. The experiments were conducted in two different locations: a fair center and a sports hall.

Material and methods

Show A (Helsinki 1995)

A total of 6037 dogs appeared at a 2-day dog show at the Helsinki Fair Center in December 1995. In one of the halls (E2), where 520 dogs were presented, samples of dog allergen were collected from three locations. Dust samples were also collected from the gallery hall and near the main entrance. The locations were chosen according to the possible airflow inside the facilities (the location of doors and other openings, floor materials, and the construction materials of the show). The dog show hall was 3730 m² in area and 37300 m³ in volume. The ventilation of the building did not recycle heat, and the return air valve closed according to the indoor air temperature during the show. The air supply of the hall came through a continuous control axial-flow fan (6–25 m³/s). The fan filter was of EU3 standard; no exhaust air filter was used.

The dust samples were collected with a vacuum cleaner using a vacuum collector nozzle developed by Allergologisk Laboratorium (ALK) A/S. A Millipore filter paper was inserted into the nozzle (38 cm² area, pore size 6 µm, ALK, Copenhagen, Denmark). The vacuuming was performed at 1300 W. In each of the locations, an area of 3 m² was vacuumed for 1 min/m². The sample filter with the nozzle box was closed with a plastic lid and sealed in a plastic bag. The nozzle was always replaced before collecting the next sample.

Immediately after the dog show, the building was cleaned: the floors were oil-mopped twice and disinfected with diluted chlorine-containing solution. Pillars and walls were washed up to 2 m in height from cranes with scrubbing brushes and Instoloc pads. All air-conditioning filters were changed, and the facility was thoroughly ventilated for 24 h.

Show B1 (Oulu 1995) and show B2 (Oulu 1996)

At a sports hall in Oulu, northern Finland, a 1-day dog show was held in October 1995 (show B1) and a 2-day show in October 1996 (show B2). A total of 3898 dogs appeared in show B1 and 3276 dogs in show B2. The effect of cleaning on the allergen levels was measured during the second dog show in 1996.

The sports hall was 452 m² in area and 161000 m³ in volume, the highest point indoors being 24 m. The airflow in the hall was controlled by two ventilators. Exhaust air was filtered, the heat was recycled, and some of the used air was recycled. Before the dog show and during the measurements performed after the show, the ventilator was working at half of its capacity and the exhaust air valve was 80% open. On the day of the show, both ventilators were operating at full capacity, and after recycling the heat, all exhaust air was discharged into the outside atmosphere.

In show B1, the surface dust samples were collected with a vacuum cleaner and an ALK adapter with filters (see Helsinki Fair Center samples). The samples were taken from different locations inside the hall before the show, on the evening of the show, and after the show when the floors had already been mopped with water. During the show, an isolated area of previously cleaned floor (1.2 m²) acted as a platform for dust accumulation. The area was measured for surface dust at the end of the show.

During the second show (B2), reservoir dust samples were collected before and after the show on wall, floor, and ceiling surfaces, including the pipes near the ceiling. More samples were taken after one intensified cleaning and two normal cleanings. The follow-up samples were always taken from the same location as the previous samples.

In show B2, dust was analyzed as ng (allergen)/g (dust) and ng/m². With ng/g, the amount of dust (and the g-value as well) varied remarkably depending on the material density and surface where the dust was collected. This could be eliminated by taking a limited area (m²) from where the dust was collected to be used as nominator. In this way, the influence of dust did not distort the assessment of allergen.

Air samples

The air samples were collected only during show B1 (Oulu, 1995) in front of the hall's air-filter grid and around the center of the hall space. During the show, the air samples could be taken only inside the ventilation operating room. The indoor air samples were collected according to the standard SFS 3860 with a vacuum collector (Reciprotor, speed of airflow 5–20 l/min; duration of collection, 5 h) on membrane filters (Millipore MAWP 037 AO). After the complete dust content had been determined, the sample was frozen at –18°C.

The samples of dog allergen were analyzed by ELISA at the ALK Laboratories in Denmark. The method of analysis has been described in more detail elsewhere (8). The detection limits of Can f 1 concentration were 10 ng/g for dust samples and 1 ng/m³ for air samples.

Results

Show A

During the dog show at the Helsinki Fair Center, the Can f 1 level on the floor of hall E2 reached 65000 ng/g (Fig. 1). The increase in all four sampling places was over 100-fold compared to base levels before the show. Twelve hours after closing and before the cleaning next morning, the Can f 1 levels on floors were at a similar level. After the intensified clean-up, and 1 week after the cleaning, the dog allergen levels on the targeted surfaces were low.

In two of the locations, the dog allergen levels increased 1 week after the cleaning (Fig. 1). At their highest, the level was 19700 ng Can f 1/g. This was 450 times greater than the situation 1 day after the cleanup. In this case, used floor felt had been put to new use uncleaned.

Show B1

Before the dog show, the total dust level in the hall's air was under 0.001–0.018 mg/m³. It was 0.039–0.085 mg/m³ during the dog show, and 0.001–0.006 mg/m³ after the show. Table 1 shows the dog allergen levels in surface dust samples. The allergen level on the exhaust air filter was 2700 ng/g before the show and 16500 ng/g after it. On the isolated floor area, 1500000–2100000 ng/g of dog

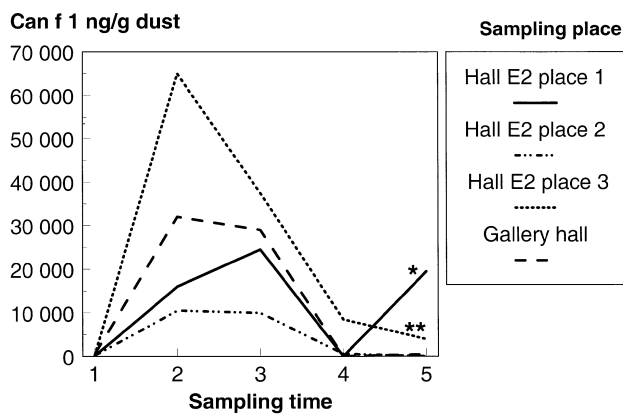


Figure 1. Dog allergen levels (Can f 1 ng/g dust) at locations of Helsinki Fair Center. Sampling time 1: before dog show; 2: right after dog show; 3: in morning after dog show, before intensified cleaning; 4: immediately after intensified cleaning; 5: 1 week after intensified cleaning. *5 m to right of hall E2 base sample location, which was covered with felt at time of collecting sample. **3 m to right of hall E2 base sample location; felt pieces were stacked on actual ground of show.

allergen accumulated during the two dog show days. On the tartan surfaces, the allergen levels were 780–1600 ng/g after the cleaning.

The total dust levels in the indoor air samples were 0.001–0.16 mg/m³ before the show, 0.04–1.16 mg/m³ during the show, and 0.001–0.03 mg/m³ after the show. The Can f 1 content was under the detection limit of the method.

Show B2

During the collection of the follow-up samples, it was noted that, despite intensified cleaning, dust had remained on uneven surfaces. The Can f 1 levels in the surface dust samples taken before the show ranged between 80 and 3544 ng/g (2 and 1210 ng/m²) (Table 2). After the second dog show, dog allergen levels ranged from 1824 to 114 459 ng/g (55 to 6360 ng/m²). After the first intensified cleanup, allergen levels in the surface samples decreased in all locations. The levels were practically similar after the second and the third cleanings. In the two samples taken near the ceiling, where no cleaning had been performed, the levels rose slightly from the levels before the show.

Discussion

Pet dander is one of the most common sensitizers in the Nordic countries, leading to allergic diseases. Symptoms can be caused by exposure to dog dander in schools, at work, and on public transport. Dog allergen can be transferred on pet owners' clothes and cause symptoms in an allergic person sitting nearby. In addition, in sensitized subjects, repeated exposure

Table 1. Surface dust samples for dog show B1 in sports hall in Oulu

Location/sample no.	Sampling date	Can f 1 content ng/g	Contamination class/ALK
0-filter (Whatman)		0	
<i>Before dog show</i>	20 Oct 1995		
1. Exhaust air filter, north		2700	1
<i>During dog show</i>	22 Oct 1995		
2. Accumulation area*		1 500 000	2
3. Accumulation area**		2 100 000	2
<i>After dog show</i>	3 Nov 1995		
4. Tartan surface***		970	0
5. Exhaust air filter, north (see sample 1)		16 500	1
<i>After dog show</i>	20 Nov 1995		
6. Tartan surface		800	0
7. Tartan surface		1600	0
8. Tartan surface		780	0

* Dust accumulation area 1.2 m × 1.2 m, accumulation of entire day of show on isolated gymnastics area.

** Dust accumulation area, accumulation platforms (1.2 m × 1.2 m), isolated gymnastics area.

*** Tartan back curve of track, inside track.

Tartan surface 2 m², gymnastics area in front of door.

Tartan surface 3 m², behind high jump area, next to wall.

Tartan surface 5 m², front curve of track, 400 m starting line, inside track.

to allergens not only causes symptoms, but also contributes to subclinical inflammation, hyperresponsiveness, and general worsening of asthma (15, 16).

Keeping a dog has become more popular in Scandinavia during the last few years. Locations used for dog shows are public facilities such as schools and sports halls. The problem occurs when those who are sensitized to dog allergen use the same facilities and develop symptoms due to the exposure to dog dander that has remained on the surfaces.

This paper presents data from three dog shows in which dog allergen levels in indoor air and on surfaces were monitored during and after the dog shows. The technique used to collect samples to measure airborne Can f 1 was not sensitive enough due to inadequate sampling time.

Based on the measurements in the Helsinki Fair Center, dog allergen levels in surface samples became over 100 times higher during the dog shows than before the shows. Intensified cleaning decreased levels in all of the locations compared to the levels taken right after the show. In only two out of the four samples did the levels decrease to the same concentration as before the shows.

The indoor air measurements at the sports hall in Oulu showed that high levels of dog allergen accumulated on surfaces during the show. Cleaning the floor carefully took away dog dander on the floors, but the allergen levels remained high near the ventilation channels. The allergen levels at the sports

Table 2. Can f 1 in dog show B2 in Oulu, before and during show and after intensified (*) and normal cleaning (**)

Location	Before show		After show		After cleaning					
	18 Oct 1996		21 Oct 1996		23 Oct 1996(*)		30 Oct 1996 (**)		6 Nov 1996 (**)	
	ng/m ²	ng/g	ng/m ²	ng/g	ng/m ²	ng/g	ng/m ²	ng/g	ng/m ²	ng/g
Restaurant lobby (3 m × 3 m)	2	80	2410	27 067	24	542	50	520	9	265
Audience gallery, concrete platform (1 × 8 m)	90	3544	1110	4948	2	90	15	395	4	139
Playing field, net (2 × 10 m)	3	129	90	4647	30	3393	3	332	5	480
Wall surface, concrete (2 × 5 m)	2	98	55	1824	3	146	4	118	1	51
Gymnasium, tartan (3 m × 3 m)	40	370	170	1743	110	1070	60	519	55	487
Track, tartan surface (1 × 6 m)	40	254	730	3988	50	337	70	452	33	252
Gymnastics area, (3 m × 3 m)	100	1276	6360	114 459	100	1111	50	533	170	2161
Track, tartan surface (1 × 5 m)	30	146	510	4283	35	198	60	386	40	305
Hall ceiling, on top of pipes (1 × 1 m)	1210	1514					3800	3803		
Hall ceiling, on top of roof beam (0.6 m × 0.6 m)	620	2243					590	4260		
Median	40	312	620	4465	33	440	55	486	21	285

hall decreased significantly from the levels measured during the show when intensified cleaning was performed. The cleaning, however, had to be repeated due to the airborne allergens that settled on surfaces for several days after the show. During the second measurement in the hall, the unit of ng/m² in addition to ng/g was used to eliminate the distortion in dog allergen levels caused by dust accumulating differently on different surfaces. The dust on the rough tartan and concrete surfaces might come off “heavier” than dust collected on smooth floor and wall surfaces, and in this case the ratio of ng/g would make the dog allergen levels lower than in a sample collected on a smooth surface. When the allergen dust was adjusted to the area (ng/m²) on which the sample was collected, the quality of the surface material did not distort the dog allergen levels.

During dog shows, dog dander and allergen accumulates on all surfaces from the floor to the ceiling. To ensure that the next users of the facilities are not exposed to high dog allergen levels, the cleaning after the show needs to be effective, and it needs to be done from the floor level all the way up to the ceiling. It also needs to be extended to such spaces as cafeterias and auditoriums outside the hall itself. However, such cleaning will not remove all allergen dust from hard-to-clean surfaces, nor from the exhaust air channels through which, due to pressure changes, harmful amounts of the allergen dust can get back into the indoor air.

Effects of cleaning procedures

In most research projects, the effect of different cleaning procedures on animal dander has remained modest. The quality of a vacuum cleaner or the use of a central vacuuming system or an air purifier has not had a

significant effect on the presence of animal dander (17–19). Washing a dog twice a week may decrease allergen levels, but the decrease was considered insufficient to prevent symptoms in an asthmatic (20). Increasing the efficiency of ventilation has also helped to decrease cat and dog allergen levels indoors (21). The use of air cleaners in living rooms and bedrooms has also been reported to improve the lung functions of asthmatic children (22).

Research by the Helsinki Public Transport Services investigating relationships between pets in public transports and allergies has shown that dog and cat allergen levels on upholstered seats in buses and trams are much higher than on subway train seats without upholstery (23). Pressurized washing of the seats decreased both dog and cat allergen levels significantly.

In schools, there are many asthmatics and pupils with allergic contact dermatitis and allergic rhinitis who might already show symptoms from the allergens in other children's clothes. Therefore, schools should not allow animal shows or have pet presentation days, both of which increase allergen levels in the indoor environment. The suitability of a facility to stage a dog show needs to be estimated according to the situation. If a hall is used for a dog show, it should be thoroughly cleaned afterward, especially the rough surfaces. Felt-type mats, which are difficult to clean, should not be used or should be removed from the public facilities after the event. Notification should be placed in the hall after the event so that dog-sensitized asthma patients may avoid the venue until cleaning is complete. Schools should not be used as a venue, as attendance at them is compulsory for children and other suitable public venues are available. Riding-schools and stables are suitable for dog shows in the winter, while sports tracks and playing fields can be used in the summer.

References

1. PLASCHKE PP, JANSON C, NORRMAN E, BJÖRNSSON E, ELLBJAR S, JÄRVHOLM B. Association between atopic sensitization and bronchial hyperresponsiveness in Swedish adults: pets, and not mites, are the most important allergens. *J Allergy Clin Immunol* 1999;**104**:58–65.
2. PLASCHKE PP, JANSON C, NORRMAN E, BJÖRNSSON E, ELLBJAR S, JÄRVHOLM B. Onset and remission of allergic rhinitis and asthma and the relationship with atopic sensitization and smoking. *Am J Respir Crit Care Med* 2000;**162**:920–924.
3. AHLBOM A, BACKMAN A, BAKKE J, et al. "Nordpet" Pets Indoors – a risk factor for or protection against sensitisation/allergy. A Nordic interdisciplinary review of the scientific literature concerning the relationship between the exposure to pets at home, sensitisation and the development of allergy. *Indoor Air* 1999;**1**:219–235.
4. VANTO T, KOIVIKKO A. Dog hypersensitivity in asthmatic children. *Acta Paediatr Scand* 1983;**72**:571–575.
5. HAAHTELA T, JAAKONMÄKI I. Relationship of allergen-specific IgE antibodies, skin prick tests and allergic disorders in unselected adolescents. *Allergy* 1981;**36**:251–256.
6. KJELLMAN B, PETTERSSON R. The problem of furred pets in childhood atopic disease. *Allergy* 1983;**38**:65–73.
7. LÖWENSTEIN H. Allergene von Katze, Hund, Rind und Pferd. *Allergologie* 1981;**4**:265–269.
8. SCHOU C, HANSEN GN, LINTNER T, LÖWENSTEIN H. Assay for the major dog allergen, Can f 1: investigation of house dust samples and commercial dog extracts. *J Allergy Clin Immunol* 1991;**88**:847–852.
9. DE GROOT H, GOEI KGH, VAN SWIETEN P, AALBERSE RC. Affinity purification of a major and a minor allergen from dog extract: serological activity of affinity-purified Can f 1 and of Can f 1-depleted extract. *J Allergy Clin Immunol* 1991;**87**:1056–1065.
10. MUNIR AKM. Exposure to indoor allergens and relation to sensitization and asthma in children. Lindköping University Medical Dissertation no. 412, 1994.
11. INGRAM JM, SPORIK R, ROSE G, HONSINGER R, CHAPMAN MD, PLATTS-MILLS TAE. Quantitative assessment of exposure to dog (Can f 1) and cat (Fel d 1) allergens: relation to sensitization and asthma among children living in Los Alamos, New Mexico. *J Allergy Clin Immunol* 1995;**96**:449–456.
12. CUSTOVIC A, SIMPSON B, SIMPSON A, HALLAM C, CRAVEN M, WOODCOCK A. Relationship between mite, cat, and dog allergens in reservoir dust and ambient air. *Allergy* 1999;**55**:612–616.
13. MUNIR AKM, EINARSSON R, SCHOU C, DREBORG SKG. Allergens in school dust. The amount of the major cat (Fel d 1) and dog (Can f 1) allergens in dust from Swedish schools is high enough to probably cause perennial symptoms in most children with asthma who are sensitized to cat and dog. *J Allergy Clin Immunol* 1993;**91**:1067–1074.
14. CUSTOVIC A, GREEN R, FLETCHER A, et al. Aerodynamic properties of the major dog allergen, Can f 1: distribution in homes, concentration and particle size of allergen in the air. *Am J Respir Crit Care Med* 1997;**155**:94–98.
15. IHRE E, ZETTERSTRÖM O. Increase in non-specific bronchial responsiveness after repeated inhalation of low doses of allergen. *Clin Exp Allergy* 1993;**23**:298–305.
16. PALMQVIST M, PETTERSSON K, SJÖSTRAND M, ANDERSSON B, LÖWHAGEN O, LOTVALL J. Mild experimental exacerbation of asthma induced by individualised low-dose repeated allergen exposure. A double-blind evaluation. *Respir Med* 1998;**92**:1223–1230.
17. DREBORG SKG, MUNIR AKM, EINARSSON R. Effect of various cleaning procedures on cat (Fel d 1) and dog (Can f 1) allergens in homes of allergic children. *Allergy* 1993;**48 Suppl 16**:106.
18. WOODFOLK JA, LUCZYNSKA CM, DE BLAY F, CHAPMAN MD, PLATTS-MILLS TA. The effect of vacuum cleaners on the concentration and particle size distribution of airborne cat allergen. *J Allergy Clin Immunol* 1993;**91**:829–837.
19. DYBENDAL T, WEDBERG WC, ELSAYED S. Dust from carpeted and smooth floors. IV. Solid material, proteins and allergens collected in the different filter stages of vacuum cleaners after ten days of use in schools. *Allergy* 1991;**46**:427–435.
20. HODSON T, CUSTOVIC A, SIMPSON A, CHAPMAN M, WOODCOCK A, GREEN R. Washing the dog reduces dog allergen levels, but the dog needs to be washed twice a week. *J Allergy Clin Immunol* 1999;**103**:581–585.
21. MUNIR AK, EINARSSON R, DREBORG S. Allergen avoidance in a day-care center. *Allergy* 1996;**51**:36–41.
22. VAN DER HEIDE S, VAN AALDEREN WM, KAUFFMAN HF, DUBOIS AE, DE MONCHY JG. Clinical effects of air cleaners in homes of asthmatic children sensitized to pet allergens. *J Allergy Clin Immunol* 1999;**104**:447–451.
23. PARTTI-PELLINEN K, MARTTILA O, MÄKINEN-KILJUNEN S, HAAHTELA T. Occurrence of dog, cat, and mite allergens in public transport vehicles. *Allergy* 2000;**55**:65–68.