

Short communication

Human hair is a potential source of cat allergen contamination of ambient air

Background: We have previously shown that airborne cat allergen levels are significantly lower in school classes using special school clothing or in classes with no pet owners. However, cat allergen is present and the levels are in fact two- to threefold higher on cat owners' than noncat owners' school clothing which is used, washed and stored at school only. This suggests that allergen is transferred to schools by routes other than clothing.

Aim: To analyse levels of cat allergen (Fel d 1) in hair from cat owners and noncat owners among children and adults.

Methods: Samples of unwashed hair (≥ 1 day prior to sampling) from adults and children with ($n = 22$) or without ($n = 22$) cats at home were collected at a hairdresser. In addition, samples of newly washed hair (adults only, $n = 11$) were collected. The hair sample was extracted and analysed for Fel d 1 content with ELISA.

Results: The geometric mean levels were more than two orders of magnitude higher in unwashed hair from cat owners, compared with noncat owners ($P < 0.0001$) and more than 10-fold higher in newly washed hair from adults. The allergen contamination of unwashed hair among noncat owners appeared higher in children than in adults ($P = 0.045$).

Conclusions: Hair may be an important source for transfer and deposition of cat allergen in schools and may explain why cat allergen is found in environments with strict allergen avoidance measures. Although it may be unrealistic to apply allergen avoidance strategies against this allergen source, it is important to be aware of it.

A.-S. Karlsson, A. Renström

Lung and Allergy Research, National Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden

Key words: allergen avoidance; allergen sampling; cat allergen; Fel d 1; human hair.

Anne-Sophie Karlsson MSc PhD
Lung and Allergy Research
National Institute of Environmental Medicine
Karolinska Institutet
Box 287
SE-171 77 Stockholm
Sweden

Accepted for publication 4 November 2004

Cat allergen and other pet allergens are transferred to public places and schools via clothing of pet owners. This 'second-hand' or 'indirect' exposure may cause worsening of symptoms among asthmatic children allergic to pets (1) and may even contribute to allergic sensitization (2, 3). Perzanowski et al. reported a surprisingly high proportion of cat-sensitized school children who had never lived in a house with a cat (83%) (4). Thus, indirect exposure to cat due to the ubiquitous presence of cat allergen in the environment seems to be relevant for allergic reactions and it is possible that moderate or intermittent exposure may even favour sensitization (5).

We have previously shown that airborne cat allergen levels are significantly lower in classes using special school clothing or pet ban (6), but not in classes where traditional allergen avoidance measures, such as removal of dust-accumulating upholstery, curtains and open shelves and increased cleaning have been implemented (7). The levels of airborne cat allergen are fivefold higher in ordinary classes with many ($> 20\%$) cat owners and levels on clothing of cat owners are sixfold higher,

compared with noncat owners' clothing (6, 8). Although allergen levels are lower in classes that use school clothing compared with conventional classes, there is cat allergen present and the levels are two- to three-fold higher on cat owners' compared with noncat owners' clothing which is used, washed and kept at school only. This suggests that other allergen sources, like hair for instance, may be important for the transfer of pet allergens to schools and other public places. However, allergen content in human hair has not been analysed previously.

The aim of the present study was to analyse levels of cat allergen (Fel d 1) in hair from cat owners and noncat owners among children and adults.

Methods

Hair sampling

Hair from adults and children (> 6 years of age) with ($n = 22$) or without ($n = 22$) cats at home was collected at a hairdresser.

Approximately 0.5–1 g of unwashed (1 day or more since last wash) hair was collected in a 50 ml preweighed Falcon tube before wetting/styling the hair. For comparison, samples of newly washed hair were collected from adults only (five cat owners and six noncat owners). Data on cat ownership, last hair wash, adult/child and any recent cat contact was recorded.

This study was approved by the Ethics Committee of the Karolinska Institutet.

Extraction of allergen from hair and Fel d 1 analysis

After weighing the tube, the dry hair sample (mean 0.88 g) was diluted 20-fold (w/v) in PBS-Tween 20 (0.1%) and allergen was extracted during rotation overnight followed by centrifugation at 1000 *g* for 10 min. All samples were analysed in a monoclonal sandwich-ELISA as presented previously, using signal amplification when necessary (AMPAK signal amplification; Dakopatts, Älvsjö, Sweden) (9). The Fel d 1 Mab-kit including standard was purchased from Indoor Biotechnologies Ltd (Cardiff, UK).

Statistics

All data were analysed using Statview 5.0 software (SAS Institute Inc., Cary, NC, USA). As the data was not normally distributed, unpaired comparisons between noncat owners and cat owners and adults and children were made using Mann-Whitney *U*-test. Comparisons between different times since hair wash were made using Kruskal-Wallis test. A *P*-value <0.05 was considered significant.

Results

Cat allergen was found in all hair samples. Generally, levels of cat allergen in unwashed hair were more than two orders of magnitude higher among cat owners (geometric mean value 179 ng Fel d 1/g of hair) compared with noncat owners (1.43 ng Fel d 1/g of hair, $P < 0.0001$). This magnitude of difference was larger among adults than in children, and cat allergen levels in hair among children without cats were 2.5 times higher compared to adults without cats ($P = 0.045$, Table 1, Fig. 1). Interestingly, although levels of cat allergen in newly washed hair were generally one-fifth compared with unwashed hair, cat owners with newly washed hair had 16-fold higher levels of Fel d 1 compared with noncat owners (geometric mean value 11.3 and 0.68 ng Fel d 1/g of hair, respectively, $P = 0.028$). A significant accumulation of cat allergen

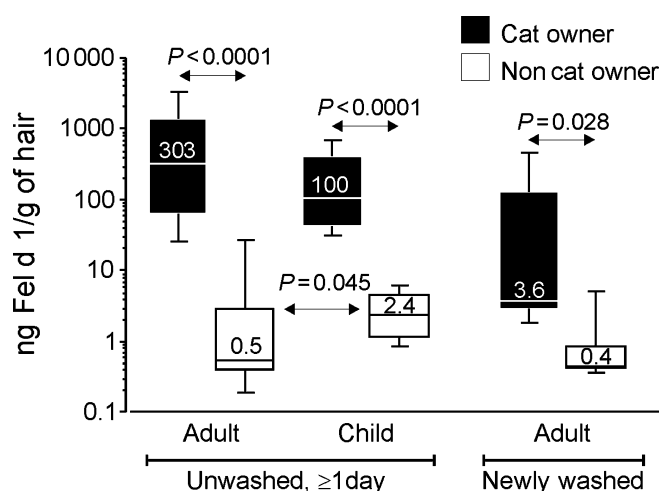


Figure 1. Cat allergen content in unwashed hair samples from adults and children, with (12 adults, 10 children) or without (11 adults, 11 children) cats at home and in newly washed hair samples from adults with ($n = 5$) or without ($n = 6$) cats at home. Box plots with medians are shown in figure where box corresponds to 25–75th percentiles and vertical lines correspond to 10–90th percentiles, respectively.

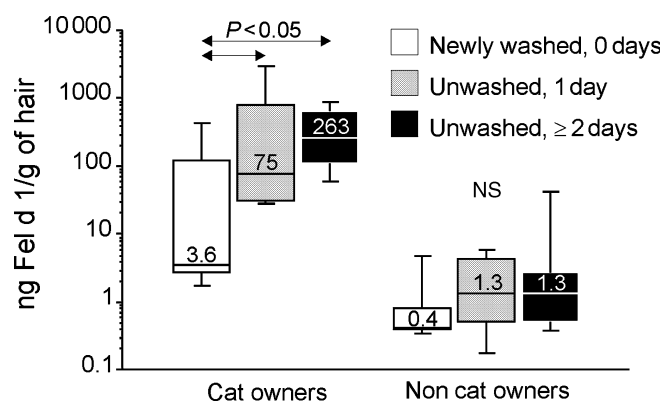


Figure 2. Cat allergen content in newly washed hair among adults with ($n = 5$) or without ($n = 6$) cats and unwashed hair among children and adults with ($n = 22$) or without cats ($n = 22$). Comparisons were made using Kruskal-Wallis test ($P = 0.038$ for cat owners, $P = 0.46$ for noncat owners). Box plots with medians are shown in figure where box corresponds to 25–75th percentiles and vertical lines correspond to 10–90th percentiles, respectively.

Table 1. Geometric mean (GM) values of cat allergen (Fel d 1) in unwashed (≥1 day prior to sampling) hair among children and adults, with or without cats

	GM (ng Fel d 1/g of hair)	Min-max
Cat owner		
Children, $n = 10$	120	30–720
Adults, $n = 12$	250	5.12–4010
Noncat owner		
Children, $n = 11$	2.20	0.70–6.23
Adults, $n = 11$	0.93	0.16–57.7

was only seen in cat owners 1 day after hair wash ($P < 0.05$, Fig. 2).

Discussion

In the present study we have shown that cat allergen levels are markedly higher in cat owners' hair compared with noncat owners' hair and that a significant difference still can be observed just after washing. The observed

difference in cat allergen levels between cat owners and noncat owners may not be surprising. However, until now there has not been any scientific evidence of this possible source of allergen contamination and our findings are therefore valuable information, especially in the context of secondary allergen avoidance. In the present study, we have not shown that cat allergen is actually released from human hair to the ambient air, although this may be a reasonable assumption. Rather high allergen levels were also found in some hair samples from noncat owners who had not had any recent direct contact with cats. However, the indirect contact with cats occurs everywhere and cannot be adjusted for.

Human hair represents a significant surface to which allergens can adhere. Assuming that an average person has 300 hairs per cm^2 of the skull (100 000 hairs in total), one may have the equivalent of 2–4 m^2 of hair surface in total, depending on hair length. This large surface together with the electrostatic features of hair may make cat allergen more inclined to adhere and may therefore represent a substantial source from which allergen deposition may occur. However, this calculation is somewhat crude as the properties of hair vary between individuals (hair colour affects density, blondes have for instance more hairs per cm^2) and ethnic groups. It was not possible to relate the amount of cat allergen to the total amount of hair (assessed by weight or surface) in the present study as more sophisticated sampling and weighing techniques would have been required (10). In the present study, we did not get information about gender and hair length. If the allergens are evenly distributed in the hair, it is likely that long hair (mostly girls) contains more cat allergen in total and hence would generate more allergen to the ambient air, than short hair.

The somewhat higher levels of cat allergen found in hair from children without cats at home, compared to adults without cats may be explained by additional allergen contamination at school as classrooms are a site of moderate and occasionally high cat allergen exposure (11). Several studies have shown that clothing is contaminated with cat allergen (8, 12–14) and it appears reasonable to assume that this applies for hair as well. This is however merely hypothetical and has not been elucidated in the present study.

In a recent study of the effect of school clothing and pet ownership ban on cat allergen levels in classrooms, we measured allergen contamination of clothing and airborne allergen in the breathing zone (pumps with filter) of cat owners and noncat owners (6). We found a significant difference between cat owners and noncat

owners in control classes and a similar difference in school clothing classes. As the clothing in the school clothing classes was only used, kept and washed at school, we sought explanations for this observed and unexpected difference. In previous studies, we have observed greater differences in airborne cat allergen levels in classes with many cat owners than in classes with few cat owners. The same applies to personal sampling (personal air samplers, rollers) among cat owners and noncat owners. This suggests that each cat owner is constantly 'feeding' the ambient air with allergen, probably depending on level of disturbance and type of clothing. De Lucca et al. found that infrequently washed clothing carries more allergen and hence increase personal exposure to airborne cat allergen, measured by intranasal sampling (14). In this context, it is therefore feasible to also consider hair as a potential allergen source with a similar allergen release.

The fact that cat allergen was also found in hair from noncat owners who reported no recent direct contact with cats, suggests that cat allergen contamination occurs elsewhere, even at home. Several studies have shown that there is cat allergen present in homes without cats, although the levels are low (2, 7, 8, 15). In addition, cat allergen was found in newly washed hair, even among noncat owners, which further illustrates how readily cat allergen contaminates the environment and how difficult removal in fact is. Moreover, a rapid accumulation of cat allergen was seen among cat owners after hair wash.

In conclusion, human hair contains substantial amounts of cat allergen and may be an important source for transfer and deposition of cat allergen in public places, schools and even homes. This may explain why cat allergen is found in environments with rather strict allergen avoidance measures, such as classes that use school clothing or have a ban on pet ownership among children's families. Although it may be unrealistic and unethical to apply allergen avoidance strategies against allergen-contaminated human hair, it is important to consider this potential allergen source, especially for an allergic child who requires exceptionally stringent allergen avoidance measures.

Acknowledgments

The authors would like to thank the hairdresser Ulrica Karlsson, Trosa and Berith Andersson, Falun for invaluable help with the hair sampling and Fernando Acevedo and Camilla Kallin for fruitful scientific discussions. This study was supported by a grant from the Majblomman Foundation.

References

1. Almqvist C, Wickman M, Perfetti L, Berglind N, Renström A, Hedrén M et al. Worsening of asthma in children allergic to cats, after indirect exposure to cat at school. *Am J Resp Crit Care Med* 2001;**163**:694–698.
2. Heissenhuber A, Heinrich J, Fahlbusch B, Borte M, Wichmann HE, Bolte G. Health impacts of second-hand exposure to cat allergen Fel d 1 in infants. *Allergy* 2003;**58**:154–157.
3. Ritz B, Hoelscher B, Frye C, Meyer I, Heinrich J. Allergic sensitisation owing to “second-hand” cat exposure in schools. *Allergy* 2002;**57**:357–361.
4. Perzanowski M, Rönmark E, Platts-Mills T, Lundbäck B. Effect of cat and dog ownership on sensitization and development of asthma among preteen-age children. *Am J Resp Crit Care Med* 2002;**166**:696–702.
5. Woodcock A, Lowe L, Murray C, Simpson B, Pipis S, Kissen P et al. Early life environmental control: effect on symptoms, sensitization, and lung function at age 3 years. *Am J Respir Crit Care Med* 2004;**170**:433–439.
6. Karlsson A-S, Andersson B, Renström A, Svedmyr J, Larsson K, Borres M. Airborne cat allergen reduction in classrooms that use special school clothing or ban pet ownership. *J Allergy Clin Immunol* 2004;**113**:1172–1177.
7. Karlsson A-S, Renström A, Hedrén M, Larsson K. Allergen avoidance does not alter airborne cat allergen levels in classrooms. *Allergy* 2004;**59**:661–667.
8. Almqvist C, Larsson P, Egmar A-C, Hedrén M, Malmberg P, Wickman M. School as a risk environment for children allergic to cats and a site for transfer of cat allergen to homes. *J Allergy Clin Immunol* 1999;**103**:1012–1017.
9. Karlsson A-S, Hedrén M, Almqvist C, Larsson K, Renström A. Evaluation of Petri dish sampling for assessment of cat allergen in airborne dust. *Allergy* 2002;**57**:164–168.
10. Price VH, Menefee E. Quantitative estimation of hair growth. I. androgenetic alopecia in women: effect of minoxidil. *J Invest Dermatol* 1990;**95**:683–687.
11. Munir A, Einarsson R, Schou C, Dreborg S. Allergens in school dust. I. 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.
12. Enberg R, Shamie S, McCullough J, Ownby D. Ubiquitous presence of cat allergen in cat-free buildings: probable dispersal from human clothing. *Ann Allergy* 1993;**70**:471–474.
13. Berge M, Munir A, Dreborg S. Concentrations of cat (Fel d 1), dog (Can f 1) and mite (Der f 1 and Der p 1) allergens in the clothing and school environment of Swedish schoolchildren with and without pets at home. *Pediatr Allergy Immunol* 1998;**9**:25–30.
14. De Lucca S, O'Meara T, Tovey E. Exposure to mite and cat allergens on a range of clothing items at home and the transfer of cat allergen in the workplace. *J Allergy Clin Immunol* 2000;**106**:874–879.
15. Bollinger ME, Eggleston PA, Flanagan E, Wood RA. Cat antigen in homes with and without cats may induce allergic symptoms. *J Allergy Clin Immunol* 1996;**97**:907–914.