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# Relationship among house-dust mites, Der 1, Fel d 1, and Can f 1 on clothing and automobile seats with respect to densities in houses

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**Background:** Locations where there are no dust mites or pets present may contain allergens that pose a risk factor for sensitizing and inducing rhinitis and asthma.

**Objective:** The purpose of this study was to investigate the relationship among the prevalence of mites and mite, dog, and cat allergens in homes, on clothing, and on automobile seats.

**Methods:** Over a 2-year period (July 1998 to July 2000), dust mite and mite, dog, and cat allergen densities were determined in homes, associated automobiles, and on the clothing of the drivers. During this period 87 homes were sampled one to five times each.

**Results:** Low levels of live and dead mites were present in most dust samples obtained from automobile seats and in 16% from clothing. Seventy-two and 50% of the home samples had  $>2 \mu\text{g}$  and  $>10 \mu\text{g}$  Der 1/g of dust, respectively, whereas 23% of automobiles seat samples had  $>2 \mu\text{g}$  Der 1/g of dust with a mean of  $1.3 \mu\text{g/g}$ . Mite and Der 1 densities were not different for homes with or without pets. However, homes with pets had significantly more Fel d 1 or Can f 1 allergen than homes without pets. Homes without cats and dogs had an average of 93 and  $29 \mu\text{g/g}$  of Fel d 1 and Can f 1, respectively, which was well above threshold levels for sensitization and induction of allergic reactions. Although most clothing had detectable levels of pet allergen, the levels of these allergens were low.

**Conclusions:** Der 1 densities in some automobiles were sufficiently high ( $>2 \mu\text{g/g}$  of dust) to be risk factors for sensitization and allergic reactions. However, most automobile seats had levels of dog and cat allergen that were well above the threshold levels considered to be risk factors for both sensitization and symptoms, regardless of the presence of a pet in the home. The presence of live and dead mites and mite, cat, and dog allergens in automobiles and on clothing suggests that both are vehicles in the dispersal of mites and mite and pet allergen.

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## INTRODUCTION

Carpets in new homes, new carpets, fabric-covered furniture, and mattresses in occupied homes initially contain no house-dust mites or house-dust mite allergens. However, in humid climates, these items eventually become infested with mites and contaminated with mite allergen. Likewise, mite allergen can be collected

from the surfaces of walls and the tops of hard furniture in homes, even though these are not locations where mites normally breed or are found.<sup>1,2</sup> In addition, measurable levels of mite allergen can be present on surfaces in public places such as hospital floors; school floors, seats, and walls; and seats of passenger trains, movie theaters, and offices where breeding populations of mites are not normally found.<sup>3–6</sup>

As expected, cat and dog allergen levels are high in carpet and sofa dust in homes with pets. However, the surfaces of carpets, sofas, hard floors, and walls in homes, schools, hospitals, day

care centers, and work places may contain significant amounts of dog and cat allergen even when no pets are present in these places.<sup>2,7–16</sup>

Carpet and fabric-covered soft furniture in homes are major reservoirs for mite, cat, and dog allergens.<sup>17,18</sup> Mites and allergens may be dispersed from these reservoirs in a number of ways. During disturbances, mites and allergen-bearing particles, particularly those of dogs and cats, become airborne and may drift and settle on such surfaces as walls and hard furniture. Also, mites and mite, dog, and cat allergens are picked up from these reservoir locations, carried on clothing and are dispersed from location to location within a house, from house to house and from houses to schools, day care centers, work places, and other public places.<sup>9,10,14,16,19–22</sup> Thus, mites and mite and pet allergens must also be distributed to automobile seats and seats in public transportation. The significance of allergens on automobile seats and on clothing in sensitizing and inducing rhinitis and asthma are not clear. Likewise, the relationship between the levels in homes, on clothing, and in other commonly used areas such as automobile seats, is unclear. The purpose of this study was to investigate clothing and automobile seats as reservoirs and vehicles for the dispersal of mites and mite, dog, and cat allergens.

## METHODS

The study protocol and informed consent form were reviewed and approved by the institutional review board at Wright State University. All participants provided informed consent and information about what kind of pet, if any, resided in the house. The study was conducted from July 1998,

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through July 2000, in the Dayton, Ohio area. A total of 198 samples from 87 different homes were collected during this 2-year period. Each home was sampled one to five times during this period. Thirty-seven, 23, 37, 35, and 66 home dust samples were collected in July 1998, August 1998, November/December 1998, July 1999, and July 2000, respectively.

#### *Dust Sampling and Analysis*

Dust samples were obtained by using a portable vacuum cleaner from two to three major mite foci within the home: sofa or chair, living room floor next to the sofa or chair, and bedroom floor next to the bed. One square meter of surface area from each sampling site was vacuumed for 2 minutes. Samples were also collected from the driver's seat (most frequently occupied seat) of the participant's automobile(s) by vacuuming the entire driver's seat for 2 minutes. All dust samples were processed as previously described.<sup>23,24</sup> Dust sampling was performed during five visits which included both humid, summer months and dry, winter months over the 2-year study: July 1998; August 1998; November/December 1998; July 1999; and July 2000. In addition, during the final visit (July 2000), samples were collected from the clothing of the participant by vacuuming the individual's dorsal side (neck to knee) for 2 minutes. Because of the small quantity of dust collected from clothing, the entire filter was analyzed. The numbers of live and dead mites were determined in each sample by using a stereomicroscope.

After analyzing each sample for live and dead mites, an aliquot of fine dust was removed from the home and automobile samples and extracted in B-PBST (0.05% bovine serum albumin in Dulbecco phosphate buffered saline with 0.002% Tween 20 and 0.05% sodium azide). Some samples were collected from leather or vinyl seats and yielded very little dust. Therefore, the entire filters for these samples, as well as those collected from the clothing, were extracted in B-PBST. The samples were mixed thoroughly, placed on

an orbital shaker overnight and then centrifuged for 5 minutes at 14,000 *g*. The resulting supernatant was collected and stored at  $-20^{\circ}\text{C}$  until assayed. The concentrations of mite (Der f 1 and Der p 1), cat (Fel d 1), and dog (Can f 1) allergens in the samples were determined according to the manufacturer's instructions using enzyme-linked immunosorbent assay kits obtained from Indoor Biotechnologies (Charlottesville, VA).

#### *Data Analysis*

For the purpose of data analysis, homes, automobiles, and clothes were sorted and analyzed three ways: 1) paired sampling, 2) mite density, and 3) pet.

#### *Paired Sampling*

Home samples (living room floor, bedroom floor, and sofa/chair) were averaged and paired with their associated automobile and clothes samples. In homes where multiple automobiles or clothes sets were sampled, a mean was calculated and data are presented as one automobile or clothing sample per house. The densities of mites and allergen contents were then compared between homes and automobiles; homes and clothes; and homes, automobiles, and clothes.

#### *Mite Density*

Homes and their associated automobiles and/or clothes for each visit were divided into two groups based on their average total (live + dead) mite counts per gram of dust: 1) homes with  $<100$  mites/g of dust and 2) homes with  $>100$  mites/g of dust. The average total mite density for each home was derived from the mean of the two or three samples collected from each home. Average mite densities and total Der 1 concentrations were compared between the homes and their associated automobiles and/or clothes.

#### *Pet*

Homes and their associated automobiles and clothes for each visit were also divided into groups based on the presence or absence of a pet. Average

mite densities and total Der 1 concentrations were compared between homes with a pet and those without. In addition, average Fel d 1 and Can f 1 concentrations were compared between homes with and without a cat and homes with and without a dog, respectively.

#### *Statistical Analysis*

Calculated results are expressed as means  $\pm$  standard errors. An analysis of variance was used to determine the level of significance between variables. When comparing homes with automobiles, homes with clothes, homes with automobiles and clothes, and automobiles with clothes, a simple correlation test (Pearson's correlation) was performed between variables. A Fisher's Z transformation test was used to calculate the significance of correlation. Correlation was defined as strong if  $r > 0.5$  ( $r^2 > 0.25$ ); moderate if  $r$  was 0.3 to 0.5 ( $r^2 = 0.09$  to 0.25); weak if  $r$  was 0.1 to 0.3 ( $r^2 = 0.01$  to 0.09); and unrelated if  $r < 0.1$  ( $r^2 < 0.01$ ).<sup>25</sup>

## **RESULTS**

### *Mite Counts and Der 1 in Homes, Automobiles, and Clothes*

Mites were found in 97.5% of the 198 home samples collected over the five sampling times. Average total mites per gram of dust for the homes at each sampling time ranged from 440.9 to 1,334.0 and are shown in Table 1. Most of these home samples (83.3%) had live mite populations during the summer months. Of the 193 home samples that had live and/or dead mites present, 139 also had mites present on the driver's seats of their associated automobiles. One hundred thirty-four of the 139 mite-positive automobile seat samples had  $\geq 20$  mites/g of dust. Thirty percent of all the automobile seat samples collected throughout the study contained live mites (range: 20 to 200 mites/g of dust). Live mites were found on some of the automobile seats sampled at all five sampling times (range: 15.8 to 44.8%) with the

Table 1. Relationship between Total Average Mite Counts (Live + Dead) per Gram of Dust Found in Houses and Automobiles

| Sampling time | n  | House           | Auto        | r <sup>2*</sup> |
|---------------|----|-----------------|-------------|-----------------|
| July '98      | 37 | 1,334.0 ± 258.3 | 74.6 ± 14.1 | 0.1574          |
| Aug '98       | 23 | 1,031.6 ± 247.9 | 81.3 ± 16.0 | 0.0121          |
| Nov/Dec '98   | 37 | 491.0 ± 88.0    | 51.8 ± 9.1  | 0.2495          |
| July '99      | 35 | 1,013.9 ± 255.9 | 51.3 ± 12.9 | 0.4348          |
| July '00      | 66 | 440.9 ± 86.2    | 42.5 ± 6.1  | 0.2247          |

\* Paired samples: correlation between the densities of mites found in homes and on their corresponding automobile seats ( $P < 0.05$  for all  $r^2$ ).

n = Number of homes and automobiles sampled.

Table 2. Relationship between Average Der 1 ( $\mu\text{g/g}$ ) Found in Houses and Automobiles

| Sampling time | n  | House      | Auto      | r <sup>2*</sup> |
|---------------|----|------------|-----------|-----------------|
| July '98      | 37 | 40.2 ± 6.6 | 1.3 ± 0.3 | 0.3026          |
| Aug '98       | 23 | 41.0 ± 9.8 | 1.2 ± 0.3 | 0.4819          |
| Nov/Dec '98   | 37 | 22.8 ± 5.4 | 2.1 ± 0.4 | 0.2694          |
| July '99      | 35 | 36.6 ± 8.7 | 1.1 ± 0.2 | 0.1249          |
| July '00      | 66 | 7.9 ± 1.5  | 1.0 ± 0.4 | 0.0405          |
| Overall avg†  |    | 25.6 ± 2.8 | 1.3 ± 0.2 |                 |

\* Paired samples: correlation between the densities of Der 1 found in homes and on their corresponding automobile seats ( $P < 0.05$  for all  $r^2$ ).

† The overall average is the mean of all individual samples.

n = Number of homes and automobiles sampled.

Table 3. Average ( $\pm$ SE) Mite Densities (Per Gram of Dust) and Der 1 Allergen ( $\mu\text{g/g}$  of Dust) in Automobiles Associated with Homes with  $<100$  Mites Per Gram of Dust and Homes with  $>100$  Mites Per Gram of Dust

| Sampling time | Auto mite densities |             | Auto Der 1 densities |           |
|---------------|---------------------|-------------|----------------------|-----------|
|               | $<100$              | $>100$      | $<100$               | $>100$    |
| July '98      | 26.7 ± 6.7          | 80.0 ± 15.6 | 0.1 ± 0.1            | 1.4 ± 0.3 |
| Aug '98       | 16.0 ± 7.5          | 95.4 ± 17.2 | 0.2 ± 0.1            | 1.4 ± 0.3 |
| Nov/Dec '98   | 20.0 ± 9.3          | 60.9 ± 10.6 | 0.5 ± 0.2            | 2.5 ± 0.5 |
| July '99      | 32.7 ± 17.0         | 58.3 ± 16.0 | 0.2 ± 0.1            | 1.5 ± 0.3 |
| July '00      | 19.4 ± 4.4          | 55.3 ± 8.9  | 0.4 ± 0.3            | 1.3 ± 0.6 |

highest prevalence found in August 1998. Average total (live + dead) mites per gram of dust found in the automobiles ranged from 42.5 to 81.3 over the five sampling times (Table 1). There was a significant overall moderate correlation between the average densities of mites in homes and in the corresponding automobiles ( $r^2 = 0.2145$ ,  $P < 0.05$ ).

Overall mean Der 1 (Der f 1 + Der p 1) allergen concentration in the home samples over the five visits was 25.6  $\mu\text{g/g}$  of dust (Table 2). Seventy-two percent of the home samples had  $>2$   $\mu\text{g}$  Der 1/g of dust and 50% had  $>10$

$\mu\text{g}$  Der 1/g of dust. One hundred sixty-four (83.3%) of the automobile samples associated with home samples with detectable quantities of Der 1 also had detectable quantities of Der 1 on their driver's seats. However, only 37 (22.6%) of these automobile seat samples had  $>2$   $\mu\text{g}$  Der 1/g of dust. The mean Der 1 allergen concentration in the automobile samples was 1.3  $\mu\text{g/g}$  of dust over the five sampling visits. Automobiles associated with homes that had  $<100$  mites/g of dust had significantly less ( $P < 0.05$ ) Der 1 allergen and mite densities compared with automobiles associated with homes

that had  $>100$  mites/g of dust over the entire study (Table 3).

During the final sampling visit (July 2000) samples were additionally collected from the clothing of the drivers of the automobiles. Mites (1 to 9 mites/sample) were recovered from 10 of the 62 sets of clothes sampled and 4 of these contained live mites. Average total mite densities in the 62 sets of homes, automobiles, and clothes were  $455.3 \pm 91.5$  and  $42.2 \pm 6.3$  mites/g of dust and  $0.4 \pm 0.2$  mites/sample, respectively. Seven of the 10 persons whose clothing samples had mites also had mites in their automobiles and in their homes. The numbers of mites recovered from clothing were weakly, yet significantly, correlated ( $r^2 = 0.0763$ ,  $P < 0.05$ ), with the total mite densities in the homes.

Der 1 was detected on 27 of the 62 clothing samples and averaged  $0.2 \pm 0.1$   $\mu\text{g/sample}$  for these samples. Twenty-three of these 27 participants also had detectable Der 1 levels in both their corresponding automobiles and homes. Significantly, there was moderate correlation between the amount of allergen in homes and on clothing ( $r^2 = 0.0985$ ;  $P < 0.05$ ). However, there was no relationship ( $r^2 = 0.0009$ ;  $P > 0.05$ ) between the amount of allergen on clothing and the density found in automobile seats. Mite densities and Der 1 allergen concentrations were not significantly different for clothing articles associated with homes with  $<100$  mites/g compared with homes with  $>100$  mites/g of dust.

#### Relationship between Total Der 1 and the Presence or Absence of Pets

There was no significant difference ( $P > 0.05$ ) in total Der 1 allergen concentrations in samples from homes with pets compared with those without pets for any sampling time except for the samples obtained during the heating season (Table 4). The overall mean mite allergen concentrations were 28.7 and 20.9  $\mu\text{g/g}$  of dust in samples from homes with pets ( $n = 120$ ) and without pets ( $n = 78$ ), respectively. Likewise, overall mean Der 1 concentrations

Table 4. Mite Allergen Densities ( $\mu\text{g}$  Der 1/g of Dust) in Homes with Pets and Homes without Pets and their Associated Automobiles

| Sampling time | Home            |                 | Auto          |               |
|---------------|-----------------|-----------------|---------------|---------------|
|               | Pet             | No pet          | Pet           | No pet        |
| July '98      | 44.0 $\pm$ 10.7 | 34.5 $\pm$ 13.7 | 1.2 $\pm$ 0.3 | 1.2 $\pm$ 0.6 |
| Aug '98       | 49.0 $\pm$ 14.2 | 28.6 $\pm$ 12.2 | 1.3 $\pm$ 0.3 | 0.9 $\pm$ 0.6 |
| Nov/Dec '98   | 29.6 $\pm$ 8.5  | 12.9 $\pm$ 3.5  | 2.2 $\pm$ 0.5 | 1.4 $\pm$ 0.6 |
| July '99      | 37.6 $\pm$ 10.8 | 34.8 $\pm$ 15.1 | 1.1 $\pm$ 0.3 | 0.9 $\pm$ 0.3 |
| July '00      | 8.2 $\pm$ 1.7   | 7.9 $\pm$ 2.2   | 0.7 $\pm$ 0.2 | 1.2 $\pm$ 0.8 |
| Overall avg*  | 28.7 $\pm$ 3.9  | 20.9 $\pm$ 4.0  | 1.4 $\pm$ 0.2 | 1.2 $\pm$ 0.4 |

\* The overall average is the mean of all individual samples.

Table 5. Average Concentration ( $\pm$ SE) of Fel d 1 ( $\mu\text{g}/\text{g}$ ) Allergen in Homes with Cats and Homes without Cats and their Associated Automobiles

| Sampling time | Home                |                  | Auto              |                |
|---------------|---------------------|------------------|-------------------|----------------|
|               | Cat                 | No cat           | Cat               | No cat         |
| July '98      | 552.4 $\pm$ 18.2    | 15.0 $\pm$ 6.4   | 123.6 $\pm$ 47.8  | 7.9 $\pm$ 2.4  |
| Aug '98       | 4118.6 $\pm$ 1507.7 | 5.9 $\pm$ 1.3    | 581.1 $\pm$ 325.2 | 11.0 $\pm$ 3.6 |
| Nov/Dec '98   | 3791.1 $\pm$ 1371.6 | 23.1 $\pm$ 9.6   | 449.1 $\pm$ 205.0 | 13.6 $\pm$ 4.7 |
| July '99      | 3585.0 $\pm$ 1510.0 | 16.8 $\pm$ 10.2  | 260.9 $\pm$ 101.6 | 8.7 $\pm$ 2.7  |
| July '00      | 1728.1 $\pm$ 835.7  | 215.3 $\pm$ 22.1 | 104.7 $\pm$ 61.9  | 14.6 $\pm$ 6.5 |
| Overall Avg*  | 2521.9 $\pm$ 533.7  | 93.0 $\pm$ 65.2  | 286.6 $\pm$ 74.0  | 13.2 $\pm$ 2.5 |

\* The overall average is the mean of all individual samples.

Table 6. Average Concentration ( $\pm$ SE) of Can f 1 ( $\mu\text{g}/\text{g}$ ) Allergen in Homes with Dogs and Homes without Dogs and their Associated Automobiles

| Sampling time | Home              |                 | Auto            |               |
|---------------|-------------------|-----------------|-----------------|---------------|
|               | Dog               | No dog          | Dog             | No dog        |
| July '98      | 365.4 $\pm$ 112.5 | 18.3 $\pm$ 10.2 | 53.4 $\pm$ 18.1 | 3.9 $\pm$ 1.3 |
| Aug '98       | 280.1 $\pm$ 182.8 | 35.9 $\pm$ 32.3 | 15.6 $\pm$ 6.0  | 1.2 $\pm$ 0.5 |
| Nov/Dec '98   | 612.9 $\pm$ 203.5 | 18.4 $\pm$ 7.3  | 71.5 $\pm$ 32.8 | 5.7 $\pm$ 1.4 |
| July '99      | 306.4 $\pm$ 117.5 | 12.2 $\pm$ 5.1  | 37.7 $\pm$ 12.5 | 3.2 $\pm$ 1.3 |
| July '00      | 235.9 $\pm$ 64.2  | 47.1 $\pm$ 18.7 | 34.8 $\pm$ 9.2  | 9.2 $\pm$ 5.4 |
| Overall Avg*  | 339.2 $\pm$ 54.1  | 29.1 $\pm$ 7.7  | 43.8 $\pm$ 8.5  | 5.8 $\pm$ 1.9 |

\* The overall average is the mean of all individual samples.

found on samples from automobile seats associated with homes with pets were similar to those of automobiles associated with homes without pets.

#### *Fel d 1 Allergen in Homes, Automobiles, and Clothing*

Samples from homes with cats ( $n = 66$ ) had significantly ( $P < 0.05$ ) more Fel d 1 than samples from homes without cats ( $n = 132$ ; Table 5). Twenty-nine and 77% of the samples from homes without cats had  $>8$  and  $>1 \mu\text{g}$  Fel d 1/g of dust, respectively. The concentration of Fel d 1 allergen was higher in the sofa/chair samples com-

pared with the carpet around this furniture, regardless of whether or not a cat was present.

The density of Fel d 1 allergen in samples from automobile seats was strongly correlated ( $r^2 = 0.2860$ ,  $P < 0.05$ ) with the density of this allergen in the associated homes. Samples from automobile seats corresponding to homes with cats exhibited 22 times more Fel d 1 allergen than samples from automobiles associated with homes without cats. However, 31.1% of the automobile seat samples associated with homes without cats had  $>8 \mu\text{g}$  Fel d 1/g of dust. In contrast, 87.9

and 95.5% of car seat samples associated with homes with cats had  $>8$  and  $>1 \mu\text{g}$  Fel d 1/g of dust, respectively.

Of the 86 individual clothes samples collected, 65.1% contained detectable levels of Fel d 1 allergen (range: 0.04 to 108.0  $\mu\text{g}/\text{sample}$ ). Twenty-two of the 56 clothes with detectable levels of Fel d 1 were associated with homes that had a cat present and these averaged  $14.7 \pm 5.6$  (range: 0.1 to 108.0)  $\mu\text{g}/\text{sample}$ . Astonishingly, of the 59 homes without cats, 34 participants had detectable levels of Fel d 1 on their clothes that averaged  $2.8 \pm 1.4$  (range: 0.04 to 33.7)  $\mu\text{g}/\text{sample}$ .

#### *Can f 1 Allergen in Homes, Automobiles, and Clothing*

Samples from homes with dogs ( $n = 74$ ) had significantly greater ( $P < 0.05$ ) average Can f 1 densities than did samples from homes without dogs ( $n = 124$ ; Table 6). Twenty-seven and 68% of the samples from homes without dogs had Can f 1 densities  $>10$  and  $>2 \mu\text{g}/\text{g}$  of dust, respectively. Likewise, 12.1 and 42.7% of automobile seat samples associated with homes without dogs had  $>10$  and  $>2 \mu\text{g}$  Can f 1/g of dust, respectively. In contrast, 54.1 and 81.1% of car seat samples associated with homes with dogs had  $>10$  and  $>2 \mu\text{g}$  Can f 1/g of dust, respectively. Can f 1 concentrations were eight times higher in automobiles associated with homes containing dogs compared with those automobiles associated with homes without a dog.

Seventy-seven percent of the 86 individual clothes samples collected had detectable Can f 1 allergen (range: 0.02 to 64.4  $\mu\text{g}/\text{sample}$ ). Fifty-five percent of these were associated with homes that had a dog present, and these averaged  $2.0 \pm 0.5$  (range: 0.03 to 10.6)  $\mu\text{g}/\text{sample}$ . Of the 45 homes without dogs, 30 of the participants' clothes had detectable levels of Can f 1 that averaged  $2.9 \pm 2.2$  (range: 0.02 to 64.4)  $\mu\text{g}/\text{sample}$ . The levels of Can f 1 on clothes were not significantly different ( $P > 0.05$ ) for homes with or without dogs.

## DISCUSSION

Automobiles are the principal means of transportation in the United States. One would expect that if mites and mite, dog, and cat allergens found in homes adhered to clothing, some would be deposited on automobile seats. In this study we found that mites and mite, dog, and cat allergens were present on clothing and on automobile seats, although at lower densities than found in typical mite and pet allergen reservoirs in homes (ie, carpets and sofas).

Our results demonstrate that in southwest Ohio the concentration of Der 1 on most automobile seats was  $<2 \mu\text{g/g}$  of dust, and thus, is not high enough to sensitize or induce allergic symptoms. However, 23% of sampled automobile seats had  $>2 \mu\text{g}$  Der 1/g dust which is sufficient to sensitize. Therefore, mite allergen density in a considerable portion of automobiles in this temperate climate was sufficient to be a risk for sensitization. As expected, automobiles associated with homes with few mites had much lower average Der 1 levels than homes with higher mite levels. Therefore, measures taken to reduce mite allergen levels in homes have a carryover effect by reducing mite allergen levels in automobile seats. The low levels of live mites, total mites, and mite allergen on automobile seats suggest that automobile seats are not mite breeding locations in this temperate climate. Although the levels of mites and mite allergen in dust obtained from clothing were low, mite and mite allergen are presumably deposited from clothing onto automobile seats. The presence of live mites on both clothing and on automobile seats suggests that they both serve as vehicles for the dispersal of mites to other locations.

The low levels of mites and mite allergen we found were consistent with results of other studies that report low mite and mite allergen levels in upholstered seats of buses and trains, as well as in public places such as hotels, rest homes, churches, primary schools, childcare centers, cinemas, offices, ski

lodges, and airplanes.<sup>3,26</sup> These reported low levels of mites and mite allergen were low presumably because conditions were not suitable for mite breeding, few mites and little mite allergen were carried on clothing, and regular cleaning removed most mites and allergen. In contrast, in Japan where passenger trains are the principal means of transportation, upholstered seats may contain significant levels of mites and mite allergen.<sup>3</sup> Uehara et al<sup>3</sup> reported that most of the upholstered commuter train seats they sampled had  $>10 \mu\text{g}$  mite allergen per square meter and  $>10 \mu\text{g}$  mite allergen per gram of dust. Because of these high levels and suitable ambient relative humidity, they suggested that train seats are mite-breeding locations in Japan.

Our study showed that in most homes (with or without pets) and their associated automobiles, cat and dog allergen levels were sufficiently high to be risk factors for both sensitization and allergic reactions. It has been suggested that  $>1$  and  $>8 \mu\text{g}$  Fel d 1 per gram of dust are risk factors for sensitization and induction of acute asthmatic symptoms, respectively.<sup>27</sup> Likewise, concentrations of  $>2$  and  $>10 \mu\text{g}$  of Can f 1 per gram of dust are the suggested levels sufficient for sensitization and allergic symptoms, respectively.<sup>12</sup> Using these threshold values, an important finding of our study was that dog and cat allergens were risk factors in both homes with pets and homes without pets. Carpet and sofa dust in 23% of homes without cats and 27% of homes without dogs contained  $>10 \mu\text{g}$  of Fel d 1 and Can f 1, respectively. Likewise, 27% of the automobile seats associated with homes without cats and 11% of homes without dogs had  $>8 \mu\text{g}$  Fel d 1 and  $>10 \mu\text{g}$  Can f1 per gram of dust, respectively. Our results clearly show that cat and dog allergen levels in homes and on the driver's seats of automobiles where there are no pets are major risk factors for sensitization and induced allergic reactions. We did not sample the passenger seats of automobiles but pre-

sumably cat and dog allergens are deposited there from clothing as well.

Our results are consistent with other studies that show an ubiquitous occurrence of Fel d 1 and Can f 1.<sup>2,9</sup> Custovic et al<sup>28</sup> also reported high levels of Fel d 1 and Can f 1 allergen in upholstered seats in trains, buses, hospitals, and other public buildings. Likewise, Partti-Pellinen et al<sup>29</sup> reported that the levels of dog and cat allergens in seats in public transportation vehicles were high enough to cause symptoms in sensitized persons.

It is difficult to evaluate the importance of the levels of dog, cat, and mite allergens we found in clothing. Little dust (usually  $<100 \text{ mg}$  per garment) can be collected by vacuum-sampling clothing.<sup>9,30,31</sup> The total amounts of mite and pet allergens on a garment are usually less than 0.5 and  $10 \mu\text{g}$ , respectively. However, high concentrations of mite, dog and cat allergen (16 to  $79 \mu\text{g/g}$  of dust) on clothing have been reported.<sup>19-22</sup> It must be kept in mind that these high concentrations are extrapolated values to report allergen per gram of dust even though little dust was collected.<sup>32</sup> Therefore, regardless of the method of reporting quantities, the importance of dog, cat, and mite allergens on clothing in sensitizing and inducing allergic symptoms is not known.

## CONCLUSION

We found that the driver's seats of automobiles and sofas/chairs and carpets in homes are major reservoirs for dog and cat allergens that can be risk factors for sensitization and allergic symptoms even when there are no resident pets. In contrast, mite allergen levels on clothing and most automobile seats were too low to be risk factors for sensitization and induction of allergic symptoms. However, because of the levels of mite, cat, and dog allergens found on clothing, our study clearly demonstrates that clothing can play a key role in the dispersal of allergens within a home and from place to place. We found no correlation between the prevalence of mites and mite allergen in homes, automobile seats, and clothing and the presence of pets in a house.

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