
Dog characteristics and allergen levels in the home

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Background: Comprehensive analyses on the effect of household dogs on dog allergen levels in the home are lacking.

Objective: To identify environmental factors and dog-specific characteristics that influence the accumulation of *Canis familiaris* 1 (Can f 1) in homes.

Methods: Dust samples were collected from the floor of infants' bedrooms at a Wayne County Health, Environment, Allergy, & Asthma Longitudinal Study birth cohort study home visit and processed for Can f 1 using a standardized protocol. Dog characteristics were based on maternal report. Homes with 1 dog were included in detailed analyses, including characterization of the dog based on coat type, dander level, and shedding.

Results: Households with dogs had higher levels of dog allergen in the home than those without dogs; however, the number of dogs in the home was not related to dog allergen levels. Homes with exclusively outdoor dogs had significantly higher dog allergen levels than homes without any dogs but significantly lower levels of dog allergen than homes with indoor dogs. Homes where the dog was allowed in the infant's bedroom had significantly higher Can f 1 levels on the child's bedroom floor than homes where it was not. The homes of altered dogs had higher Can f 1 levels than did their unaltered counterparts.

Conclusions: Dogs in the home corresponded to dog allergen in the home. Time the dog was indoors and whether it was allowed on the vacuumed surface mattered. No dog characteristic, other than altered status, was associated with allergen levels in the home.

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INTRODUCTION

Dog allergy is a public health burden¹ highly associated with both asthma and allergic rhinitis.² Contributing to this disease burden is the presence of approximately 53 million domestic dogs in the United States, residing in approximately 33% of US homes.³ The magnitude of this problem makes it important to identify factors related to the accumulation of the major dog allergen *Canis familiaris* 1 (Can f 1) in homes.

Several studies evaluating dog allergen levels in homes were identified from the literature; however, these studies had important limitations.^{4–10} Some publications presented dog allergen levels^{4–6} or “clinically relevant” thresholds⁷ where the authors stratified households by dog ownership, but they did not take into account whether the dogs could have been kept exclusively outdoors. Other publications did not present findings separately for homes with dogs,^{8–10} and none addressed whether the dog was allowed in the room from which the environmental sample was collected. The aim of our analyses was to identify environmental factors and dog-spe-

cific characteristics that influence the accumulation of Can f 1 in homes, specifically in children's bedrooms.

METHODS

The Wayne County Health, Environment, Allergy, & Asthma Longitudinal Study (WHEALS), a population-based birth cohort, has been described fully elsewhere.¹¹ Briefly, pregnant women who resided in urban and suburban areas of Detroit, Michigan, were recruited during a second or third trimester prenatal visit to a Henry Ford Health System obstetrics clinic. Interviews were conducted at recruitment and at a 1-month postpartum home visit. Written consent was given by participants at the time of study recruitment.

Dust samples were collected from the infant's bedroom floor at 1 month post partum and processed thereafter using a standardized protocol.^{11,12} Dust was obtained by placing a closely fitting, unbleached muslin collection sock on the nozzle of a vacuum, and the nozzle was used to vacuum a 1-m² area of the floor along the side of the infant's bed for 2 minutes. The collection sock, complete with dust specimen, was placed in a sterile plastic bag, frozen to –80°C, and shipped to our collaborating laboratory at the Medical College of Georgia. Dust was analyzed by emptying the dust sample from the collection sock into a funnel fitted with a mesh filter (pore size, 292 nm) connected to a 10 × 75-mm sample tube. The tube and its contents were then shaken on an orbital shaker for 1 hour, allowing the crude dust sample to separate into coarse debris and fine dust. The filtered, fine dust was then weighed and extracted before being analyzed

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for Can f 1. The dust sample was assayed using standard monoclonal antibody assays (Indoor Biotechnologies Ltd, Charlottesville, Virginia) with a lowest detectable limit of 0.5 ng/mL. Samples with undetectable values were assigned half the value of the lowest detectable limit or 0.25 ng/mL. Results were converted to micrograms of allergen per gram of dust to make them comparable to the literature. Additional dust samples were collected from the home; however, because of financial constraints, only dust from the floor of the infant's bedroom was analyzed for Can f 1.

Dog characteristics were based on maternal report during the personal interview in her home conducted 1 month after delivery. Women were asked how many dogs were living in the home, and the following data were collected for each dog: breed or breeds, sex, reproductive status (neutered or spayed vs not), weight, number of months the dog lived in the home, average time indoors daily, and whether the dog was allowed in the infant's bedroom. Sex was determined by asking if the dog was male or female and altered status clarified by asking whether the dog had been spayed or neutered. Information on flooring characteristics was collected by trained field staff at the time of the dust sample collection, and urban and suburban classification was based on city of residence at the time of the collection (all those living in Detroit were considered to be living in an urban environment). If a dog was kept indoors 1 or more hours per day on average, the home was categorized as having an indoor dog, whereas dog-keeping households where dogs were not kept indoors were categorized as having outdoor dogs. In homes where multiple dogs were kept and allowed inside the home, the home was categorized as dogs allowed in the infant's bedroom if any dog was allowed in the infant's bedroom.

Homes with 1 dog were selected for additional dog characteristic analyses. These analyses included characterization of the dog based on coat type (short, medium, long, thick, or wire), dander level (low, regular, or high), body hair status of dog (present or absent), whether the dog was single or double coated, and shedding amount (little, average, seasonal, or constant). Dogs were assigned to these categories based on their breed standards.^{13,14} Nonpurebred dogs were not necessarily excluded from analyses. If a dog was listed as 2 separate breeds, the breed standards for these 2 types of dogs were compared, and if any categorization was common between them, the shared trait was assigned to the dog in question. For dogs of more than 2 breeds or for dogs of unknown breeds, no values were assigned.

Because Can f 1 was not normally distributed, geometric means were used to summarize the data. Spearman correlations were used to assess the association of Can f 1 and various dog characteristics, such as time indoors. For 2-group comparisons, Wilcoxon rank sum statistics were calculated. For comparisons of groups with 3 or more levels, Kruskal-Wallis tests were used for nominal variables and Jonckheere-Terpstra tests for trend for ordinal variables. For multivariable analyses, variables with a $P < .15$ in univariate analyses were entered into the regression model. Can f 1 was log-

Table 1. Detection Rates of Can f 1 by Household Dog Composition, WHEALS Cohort, Detroit, Michigan

No. of dogs in household at 1-month interview	Detectable, No. (%)	Nondetectable, No. (%)	Total, No. (%)
0	376 (50.9)	362 (49.1)	738 (74.4)
1	175 (91.6)	16 (8.4)	191 (19.3)
2	45 (90.0)	5 (10.0)	50 (5.0)
3	12 (92.3)	1 (7.7)	13 (1.3)
Total	608 (61.3)	384 (38.7)	992 (100)

Abbreviation: WHEALS, Wayne County Health, Environment, Allergy, & Asthma Longitudinal Study.

transformed before inclusion in the regression models because of skewness of the data. This research was approved by the Henry Ford Health System institutional review board.

RESULTS

There were 992 families with dog allergen data available at the 1-month home visit. Of these 992, 384 (38.7%) had nondetectable Can f 1 levels. As indicated in Table 1, these 384 homes are largely, but not exclusively, without dogs. Most homes with dogs (91.3%) and half of all homes without dogs (50.9%) had detectable Can f 1 levels in the home.

Table 2 provides Can f 1 levels by household dog ownership. Households with dogs were significantly more likely to have detectable Can f 1 levels and higher levels of dog allergen in the home compared with households without dogs (both $P < .001$). Homes with exclusively outdoor dogs with detectable allergen had significantly higher Can f 1 levels than homes without any dogs ($P = .004$) but significantly lower levels than homes with indoor dogs ($P < .001$); however, the percentage of homes with detectable Can f 1 levels was significantly different only between homes with indoor vs outdoor dogs. Figure 1 shows a significant trend of increasing dog allergen level associated with increased dog presence in the home for 4 levels of dog ownership (no dog, outdoor dog[s] only, indoor dog[s] not allowed in the infant's bedroom, and indoor dog[s] allowed in the infant's bedroom) (test for trend $P < .001$). One-dog homes where the dog was allowed indoors were further assessed in Table 2. Homes where the dog was allowed the run of the house, allowed in the mother's bedroom, or allowed in the infant's bedroom all had significantly higher levels of Can f 1 than homes where they were not ($P = .003$, $P = .001$, and $P = .001$, respectively).

Spearman correlations for homes with dogs and detectable levels of Can f 1 are indicated in Table 3. Total dog months ($P = .005$) and total number of hours the dogs were indoors daily ($P < .001$) were positively, although modestly, correlated with dog allergen in the home ($r = 0.19$ and $r = 0.30$, respectively). Dog owners in urban environments tended to keep their dog indoors for a shorter duration of time daily than their suburban counterparts (Wilcoxon rank sum test $P = .004$, data not shown). One-dog homes were further assessed. In homes

Table 2. Can f 1 Levels by Household Dog Ownership, WHEALS Cohort, Detroit, Michigan

Dog ownership	No.	No. (%) of homes with nondetectable Can f 1	χ^2 P value	Homes with detectable Can f 1 only		
				No.	Can f 1 geometric mean, $\mu\text{g/g}$ (95% CI)	P value
Any dog in home			<.001			<.001 ^b
Yes	254	22 (8.7)		232	1.24 (0.91–1.71)	
No	738	362 (49.1)		376	0.055 (0.048–0.063)	
Outdoor only dog homes ^a			.33			.004 ^b
Yes	30	12 (40.0)		18	0.13 (0.07–0.23)	
No (no dogs)	738	362 (49.1)		376	0.055 (0.048–0.063)	
Dog homes ^a			<.001			<.001 ^b
Outdoor only	30	12 (40.0)		18	0.13 (0.07–0.23)	
Indoor any hour	219	10 (4.6)		209	1.59 (1.14–2.21)	
No. of dogs			.91			.82 ^c
1	191	16 (8.4)		175	1.21 (0.85–1.74)	
2	50	5 (10.0)		45	1.23 (0.56–2.69)	
3	13	1 (7.7)		12	1.86 (0.35–9.99)	
In 1-dog homes where dog allowed indoors			.99			
Hours dog indoors						.20 ^b
≤ 12	31	2 (6.4)		29	0.82 (0.32–2.07)	
> 12	142	8 (5.6)		134	1.60 (1.06–2.42)	
Allowed run of house			.18			.003 ^b
Yes	120	5 (4.2)		115	2.02 (1.33–3.07)	
No	53	5 (9.4)		48	0.61 (0.29–1.29)	
Allowed on furniture			.21			.08 ^b
Yes	70	2 (2.9)		68	2.11 (1.20–3.72)	
No	103	8 (7.8)		95	1.07 (0.65–1.76)	
Allowed in mother's bedroom			.74			.001 ^b
Yes	102	5 (4.9)		97	2.36 (1.46–3.79)	
No	71	5 (7.0)		66	0.68 (0.38–1.20)	
Allowed on mother's bed			.06			.03 ^b
Yes	48	0 (0.0)		48	2.66 (1.36–5.22)	
No	125	10 (8.0)		115	1.09 (0.70–1.71)	
Allowed in infant's bedroom			.95			.001 ^b
Yes	88	5 (5.7)		83	2.56 (1.50–4.37)	
No	85	5 (5.9)		80	0.77 (0.47–1.27)	
Allowed on infant's bed			.99			.74 ^b
Yes	6	0 (0.0)		6	1.94 (0.13–29.4)	
No	167	10 (6.0)		157	1.41 (0.96–2.06)	

Abbreviations: CI, confidence interval; WHEALS, Wayne County Health, Environment, Allergy, & Asthma Longitudinal Study.

^a Five homes were excluded because they had both indoor and outdoor dogs.

^b Wilcoxon rank sum test.

^c Jonckheere-Terpstra test for trend.

where the dog was allowed indoors, only the number of months the dog lived at the home ($P = .07$) and dog weight in homes where the dog was not allowed in the infant's bedroom ($P = .052$) were close to statistical significance.

Table 4 addresses whether urban environment or flooring type at the site of sampling affected Can f 1 levels. Among homes with 1 or more inside dogs, higher levels of Can f 1 were found in suburban homes (geometric mean, 2.72 vs 0.53; $P < .001$) with a similar pattern evident when restricted to 1-dog homes, whether or not the dog was allowed in the room sampled. Flooring type was also assessed and, as indicated in Table 4, was not significantly related to Can f 1 levels in the home, although the means for carpeted floors

were consistently higher than those for smooth floors. Neither type of carpet (plush pile vs Berber) nor amount of bedroom carpeted (rug vs wall-to-wall carpet) was associated with Can f 1 levels in homes with indoor dogs where dogs were allowed in the infant's bedroom (Wilcoxon rank sum test: type of carpet, $P = .36$; amount of carpet, $P = .75$; data not shown).

Characteristics specific to dogs are indicated in Table 5. No canine characteristic was significantly associated with Can f 1 levels in 1-dog homes with detectable levels of Can f 1 when the dog was allowed in the infant's bedroom. In homes with detectable Can f 1 levels where their 1 dog was allowed indoors but not in the infant's bedroom, only the

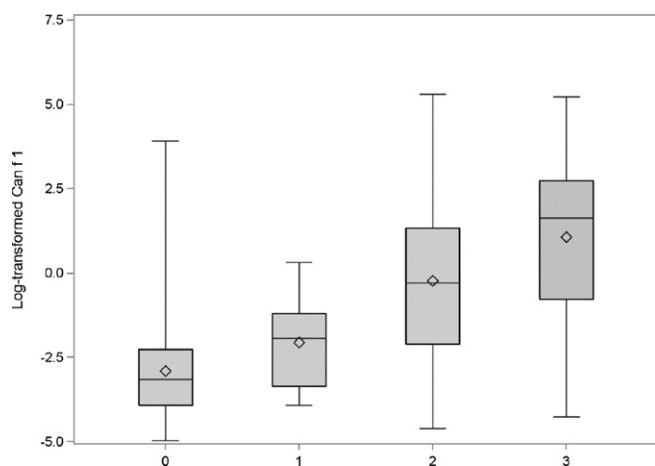


Figure 1. Box plot of detectable Can f 1 levels on infant's bedroom floor by household dog ownership, Wayne County Health, Environment, Allergy, & Asthma Longitudinal Study cohort, Detroit, Michigan. 0 indicates no dogs (n = 376); 1, outdoor dog(s) only (n = 18); 2, dog(s) allowed indoors but not in the infant's bedroom (n = 109); and 3, dog(s) allowed in the infant's bedroom (n = 105).

dog's altered status was significantly associated with Can f 1 levels, with spayed or neutered dogs having higher levels of Can f 1 than their unaltered counterparts ($P < .001$).

Multivariable analyses showed that, on average, in households with detectable Can f 1 levels where the dog was allowed indoors but not in the infant's bedroom, only whether

Table 3. Correlation of Can f 1 Levels to Dog and Home Characteristics Among Homes With Dogs Having Detectable Can f 1 Levels, WHEALS Cohort, Detroit, Michigan

Characteristic	No.	Spearman correlation (r)	P value
No. of dogs	232	0.03	.69
Total dog weight ^a	230	-0.03	.70
Total dog months	232	0.19	.005
Total dog hours indoors	232	0.30	<.001
In 1-dog homes where the dog was allowed indoors			
Dog weight ^a	161	0.05	.53
Allowed in infant's bedroom	82	0.22	.052
Not allowed in infant's bedroom	79	-0.14	.21
Dog months	163	0.14	.07
Allowed in infant's bedroom	83	0.11	.33
Not allowed in infant's bedroom	80	0.14	.23
Dog hours indoors	163	0.10	.18
Allowed in infant's bedroom	83	-0.06	.62
Not allowed in infant's bedroom	80	0.11	.35

Abbreviation: WHEALS, Wayne County Health, Environment, Allergy, & Asthma Longitudinal Study.

^a Missing data.

Table 4. Can f 1 Levels in Homes With Detectable Levels Only by Residential Characteristics, WHEALS Cohort, Detroit, Michigan

Characteristic	No.	Geometric mean (range)	P value ^a
Any dogs in the home			
Environment			<.001
Suburban	113	2.72 (1.75–4.24)	
Urban	107	0.53 (0.35–0.80)	
Flooring type			.69
Carpeted	172	1.31 (0.89–1.91)	
Bare	57	1.09 (0.60–1.99)	
No dogs in the home			
Environment			.97
Suburban	155	0.057 (0.046–0.070)	
Urban	148	0.057 (0.046–0.070)	
Flooring type			.46
Carpeted	308	0.057 (0.049–0.067)	
Bare	64	0.045 (0.035–0.058)	
1-Dog homes (homes with detectable levels only) where dog is ever allowed inside			
Dog allowed in infant's bedroom			
Environment			.08
Suburban	61	3.45 (1.88–6.33)	
Urban	22	1.13 (0.37–3.42)	
Flooring type			.46
Carpeted	54	2.84 (1.39–5.80)	
Bare	28	2.07 (0.90–4.72)	
Dog not allowed in infant's bedroom			
Environment			.02
Suburban	30	1.66 (0.71–3.84)	
Urban	50	0.49 (0.27–0.89)	
Flooring type			.08
Carpeted	60	1.00 (0.56–1.80)	
Bare	18	0.34 (0.12–0.95)	

Abbreviation: WHEALS, Wayne County Health, Environment, Allergy, & Asthma Longitudinal Study.

^a Wilcoxon rank sum test.

the dog was spayed or neutered was related to Can f 1 levels ($P < .001$, data not shown). No factors in the multivariable analysis were predictive of Can f 1 levels where the dog was allowed in the infant's bedroom (all $P > .05$, data not shown).

DISCUSSION

Dog ownership was related to higher Can f 1 levels in the home. Even homeowners who kept their dogs outdoors had significantly higher levels of Can f 1 than did homes with no dogs. Increasing time of the dog in the home corresponded with increased levels of Can f 1. In homes with a single dog, we found that if the dog was allowed in the infant's bedroom then that floor surface had higher Can f 1 levels compared with homes where the dog was allowed indoors but not in the

Table 5. Can f 1 Levels by Canine Characteristics in 1-Dog Homes (Homes With Detectable Levels Only) Where Dog Is Ever Allowed Inside, WHEALS Cohort, Detroit, Michigan^a

Characteristics	No.	Geometric mean (range)	P value
Dog allowed in infant's bedroom			
Dander level			.99 ^b
Low	5	2.58 (0.05–130.2)	
Regular	44	2.40 (1.18–4.88)	
High	7	2.41 (0.31–18.5)	
Shedding			.27 ^b
Little	12	2.09 (0.38–11.3)	
Average	34	1.59 (0.74–3.43)	
Seasonal	1	2.45	
Constant	8	9.32 (1.04–83.8)	
Single vs double coat			.83 ^c
Single	5	2.56 (0.05–130.2)	
Double	64	3.04 (1.73–5.34)	
Coat type			.09 ^b
Short	34	1.80 (0.85–3.80)	
Medium	12	8.03 (1.64–39.3)	
Long	8	0.53 (0.08–3.59)	
Thick	0		
Wire	1	3.72	
All dogs			.38 ^c
Female	36	1.88 (0.77–4.56)	
Male	47	3.26 (1.66–6.38)	
Altered status			.16 ^c
Fixed	62	3.19 (1.75–5.84)	
Unaltered	21	1.34 (0.41–4.36)	
Altered dogs only			.10 ^c
Female	30	1.89 (0.74–4.81)	
Male	32	5.23 (2.40–11.4)	
Unaltered dogs only			.61 ^c
Female	6	1.82 (0.05–69.0)	
Male	15	1.19 (0.33–4.22)	
Dog not allowed in infant's bedroom			
Dander level			.44 ^b
Low	5	1.77 (0.22–14.5)	
Regular	53	0.54 (0.30–0.97)	
High	6	0.66 (0.03–13.7)	
Shedding			.42 ^b
Little	12	1.99 (0.55–7.21)	
Average	43	0.58 (0.29–1.18)	
Seasonal	5	0.57 (0.07–4.47)	
Constant	5	0.42 (0.02–11.2)	
Single vs double coat			.18 ^c
Single	6	1.91 (0.39–9.50)	
Double	64	0.66 (0.38–1.15)	
Coat type			.41 ^b
Short	39	0.53 (0.27–1.04)	
Medium	8	1.68 (0.27–10.3)	
Long	6	2.95 (0.19–45.8)	
Thick	3	0.49 (0.004–56.5)	
Wire	2	1.16 (0.001–935.8)	
All dogs			.71 ^c
Female	30	0.84 (0.38–1.39)	
Male	50	0.73 (0.37–1.94)	

Table 5. (Continued) Can f 1 Levels by Canine Characteristics in 1-Dog Homes (Homes With Detectable Levels Only) Where Dog Is Ever Allowed Inside, WHEALS Cohort, Detroit, Michigan^a

Characteristics	No.	Geometric mean (range)	P value
Altered status			<.001 ^c
Fixed	30	3.09 (1.39–6.87)	
Unaltered	50	0.34 (0.20–0.57)	
Altered dogs only			.97 ^c
Female	13	3.02 (0.85–10.7)	
Male	17	3.15 (1.00–9.94)	
Unaltered dogs only			.82 ^c
Female	17	0.32 (0.12–0.82)	
Male	33	0.35 (0.18–0.68)	

Abbreviation: WHEALS, Wayne County Health, Environment, Allergy, & Asthma Longitudinal Study.

^a Not all characteristics are known for each dog; therefore, there are missing data.

^b Kruskal-Wallis test.

^c Wilcoxon rank sum test.

infant's bedroom. Although Can f 1 levels did not differ significantly between carpeted and noncarpeted bedrooms, there were generally higher levels of allergen detected from carpeted samples, with this difference almost achieving statistical significance in 1-dog homes where the dog was not allowed in the infant's bedroom.

Our study had a higher percentage of homes in which Can f 1 was not detectable (38.7%) compared with the study of Arbes et al,⁸ who analyzed the National Health and Nutrition Examination Survey (NHANES) data (4.4% from bedroom floors). There are many possible reasons for a higher prevalence of undetectable Can f 1 in our study. The 2 most likely reasons are that we only measured Can f 1 in samples from the floor of the infant's bedroom in contrast to measuring allergen from parental bedrooms and that our sample of homes we studied may have contained a higher percentage of urban dwellings, which are much less likely to have dogs compared with suburban homes (information on Can f 1 levels by urban environment was not presented in the NHANES summary). Because Arbes et al did not present data on percentage of homes with detectable Can f 1 levels separately for homes with and without dogs, we are not able to directly compare our rates of Can f 1 detection. However, just more than half of all zero-dog homes in our study had detectable Can f 1 levels, suggesting that Can f 1 may last longer in the environment than is commonly thought.

Multivariable models suggested that whether the dog was spayed or neutered was most strongly associated with dog allergen levels in homes with detectable dog allergen levels where the dog was allowed indoors but not in the infant's bedroom. Because the length of time the dog was in the home was assessed as opposed to recording the age of the dog (which is often related to altered status), taking into account dog age may clarify the relationship between a dog's hormone level and its allergen production. In homes with detect-

able dog allergen levels where the dog was allowed in the infant's bedroom, there were no factors, other than the presence of a dog, related to dog allergen levels. Because Can f 1 levels were significantly different in our study homes dependent on both whether the dog was allowed in the infant's bedroom and duration of time the dog spent indoors daily, it would be reasonable that if time the dog was allowed in the infant's bedroom had been captured, specific dog characteristics in our model, such as dander level or shedding status, might have been found to significantly influence Can f 1 levels.

There are some important clinical implications of our findings. The fact that we found lower Can f 1 levels in urban vs suburban homes is not surprising given that dogs in urban environments spent less time inside our study homes. However, confirming such a relationship has clinical relevance in that it implies that some degree of environmental control may be achieved by instructing allergic patients to have their dog spend more time outdoors if this is feasible and safe for the pet. We also found that Can f 1 levels were higher in homes with dogs that were spayed or neutered. To our knowledge, this relationship has not been previously reported. If such a relationship is confirmed in dogs, this may be clinically useful information that patients and their physicians should discuss. Lastly, although not quite statistically significant ($P = .08$), there was a pattern of lowered dog allergen in homes with bare floors where the dog was not allowed in the bedroom. Future studies should further investigate this preliminary evidence that bare floors may be better in households with both dogs and individuals with allergy.

A limitation of this analysis included having a relatively small sample size for dog characteristic analyses. Also, age of the dog was not captured, which may have influenced Can f 1 levels. Furthermore, dog breed was based on maternal report rather than being assessed by our study staff; however, it was beyond the scope of the study to personally assess dog characteristics. Quantifying Can f 1 levels directly from the dog may have made our study more comparable to some others in the literature, but because the study focuses on determinants of allergic risk from the home environment, our quantification of dog allergen levels from the indoor environment may be more directly related to health outcomes. Despite these potential limitations, our study had numerous strengths. Our study is an unselected, population-based birth cohort study with a large sample size. Furthermore, our study homes were evenly divided between urban and suburban homes and had varying numbers of dogs and dog-keeping practices and a diverse collection of breeds between them.

Similar to other studies, we found that homes with dogs had higher Can f 1 levels than homes without dogs^{4–6}; however, our research found that there are additional factors that influence dog allergen levels that are often not measured. Whether the dog was allowed in the home or allowed in the

area from which the environmental sample was collected and the amount of time the dog was indoor mattered. Consideration of these factors is essential to accurately assess factors that influence dog allergen (and its abatement) in the home.

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