A cross-sectional analysis of pet-specific immunoglobulin E sensitization and allergic symptomatology and household pet keeping in a birth cohort population

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ABSTRACT

It is unknown whether family members with detectable specific immunoglobulin E (sIgE) and/or allergic symptoms to pets are more or less likely to reside in a household with pets. We cross-sectionally investigated potential relationships between family members' allergic sensitization and symptoms to dogs and cats and current household pet-keeping practices, using birth cohort data. Blood samples taken from children enrolled in a birth cohort and their biological mothers and fathers, when the children were aged 18 years, were assessed for sIgE to dog and cat allergens. Interviews assessed subjects' self-reported pet exposure symptoms, current household pet-keeping practices, and socioeconomic characteristics. Overall, household dog or cat keeping was not associated with sIgE to these animals and/or self-reported allergic symptoms in the presence of these animals, even after controlling for factors such as education and household income. In subgroup analyses, current household dog keeping among dog-symptomatic teens ($n = 40$) was significantly lower than among teens who were not dog symptomatic ($n = 289$), at 48.8 and 61.1%, respectively ($p = 0.036$). Current household cat keeping was significantly lower among cat-symptomatic mothers ($n = 27$) compared with mothers who were not cat symptomatic ($n = 120$), at 24.3 and 37.0%, respectively ($p = 0.015$). However, when considering those who were both sensitized and reported symptoms, only the mother and cat-keeping associations persisted ($p = 0.049$). When cat-sensitized mothers report allergic symptoms to cats, these pets may be less likely to be kept in homes. Elevated dog and cat allergen sIgE does not appear to be associated with the keeping of these pets.

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Allergy and asthma are complex and broad public health challenges, with historical data illustrating that the prevalence of these disorders increased through the last part of the 20th century in most developed and developing nations.^{1–3} Although asthma-related mortality and morbidity rates have slowed in recent years in Westernized countries,^{4,5} current global prevalence warrants concern as well as bolstered efforts to identify risk and preventive factors associated with these conditions.

A contemporary theory related to the “hygiene hypothesis”^{6–8} posits that early life exposures to livestock, domestic pets, and their diverse spectrum of microbes reduces the risk of developing allergy-related respiratory disorders.^{9–11} Although pets are common triggers for allergy / asthma, numerous research groups

have indicated that the presence of one or more dogs in a home may actually lower rates of allergic sensitization and asthma in young children exposed in early life.^{12–16} The mechanisms that drive this protective effect are not understood.^{17,18} However, it has been shown that the early life intestinal microbial community, which we and others hypothesize may be impacted by household dogs' influence on the environmental microbiome,^{19,20} may alter immune responses and thereby promote tolerance to common allergens in contrast to allergic sensitization.

A research question relevant to studies focused on pets and allergic disease risk is whether observed inverse associations can be explained by selection bias. Children in homes with a family member with allergies may be at increased risk, genetically, but the family may be less likely to keep pets. This tendency of “selective avoidance”²¹ in pet-keeping practices, specifically as it relates to health-related decisions in families, has been highlighted recently in literature as an area requiring more focused study.^{22,23} However, clinicians often remark that, despite patients' personal or family members' allergic symptoms being triggered in the presence of pets and efforts to educate patients on risk, people do not avoid pet keeping.

Sensitization to pets alone, defined by sIgE, does not always lead to the presence of allergic symptoms that

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would likely have a greater impact on pet-keeping choices.^{24,25} Using cross-sectional data from the 18-year follow-up contact with families from the Detroit area CAS birth cohort population, we investigated potential relationships between allergic sensitization to dogs and cats and/or participants' self-reported allergic symptoms in the presence of these animals with the keeping of these pets in homes.

METHODS

Described in greater detail elsewhere,^{16,26,27} the Childhood Allergy Study (CAS) is a longitudinal birth cohort study initiated in 1987 that tracked the allergy-related outcomes of children born to mothers in metropolitan Detroit, MI, who were members of the health maintenance organization owned by the Henry Ford Health System. Follow-up interviews at age 18 years were conducted with the teens as well as their biological parents to record lifestyle behaviors and to collect information on participants' current household pet-keeping practices. Blood was also collected from the teens and their parents for subsequent allergen-specific immunoglobulin E (sIgE) analysis. Written consent was obtained from all participants. The study was approved by the Henry Ford Health System Institutional Review Board.

A primary variable in this study was current keeping of dogs or cats in the homes of CAS children and their parents when the children were aged 18 years. Data on these current household pet-keeping practices were also collected for the child's mother and father if they lived in different residences from the child. Current household pet keeping was defined as self-reported keeping of dog(s) or cat(s) staying inside of the participant's home for ≥ 12 hours a day, on average.^{27,28}

Persons were identified as being sensitized to either dogs or cats if their serum sIgE (E5) for dog or cat was ≥ 0.35 kU/L. Allergen sIgE analysis was performed using the Pharmacia UniCAP system (Pharmacia-Upjohn Diagnostic Division, Kalamazoo, MI). Both teens and their parents were asked, using an identical questionnaire, if they ever had any of a list of allergic symptoms when in the presence the dog or cat. Three allergic symptom groups were used for classification purposes: Asthma related (including symptoms of coughing, wheezing, tightness in chest, and shortness of breath), rhinoconjunctivitis (including symptoms of runny/stuffy nose, sneezing, and itchy/watery eyes), and hives (including symptoms of red/itchy bumps on skin).

Additionally, the following demographic variables were assessed to account for possible confounding: parental education level, marital status and household income, and number of child siblings in the home.

Statistics

Analyses were restricted to participants (children, mothers, or fathers) who had sIgE results and interview data on allergic symptoms at the child's 18-year follow-up contact.

Proportions of current dog and cat keeping in the home within allergic sensitization and symptom groups separately for teens, mothers, and fathers were compared with chi-square testing. These analyses were repeated for the subgroup of families in which all three family members (*i.e.*, teen, mother, and father) had their blood drawn at the same clinic visit. Logistic regression was used to calculate odds ratios (OR; crude and adjusted) with 95% confidence intervals (CIs). SAS Version 9.2 (Release 2; SAS Institute, Inc., Cary, NC) was used for all analyses.

RESULTS

Differences between CAS participants included (interview and blood sample; $n = 555$) and those excluded (interview and no blood sample; $n = 280$) were limited to parental age at the time of the child's birth. The mean age of mothers included, versus mothers not included, was 29.0 years (4.4) and 28.0 years (4.6), respectively ($p = 0.002$), and the mean age of fathers included was 31.3 years (4.9) versus 30.4 years (5.5), respectively ($p = 0.031$).

Characteristics of the study participants are provided in Table 1. In total, 555 teens, 435 mothers, and 298 fathers were included in the analysis. In addition, there were 266 families with teen, mother, and father data available for aggregate analysis. The mean ages (SD) of the children, mothers, and fathers at the 18-year follow-up were 18.3 (0.5), 47.7 (4.3), and 50.1 (4.8) years, respectively. The study population was predominantly white ($>94\%$). More than 84% of the parents had at least some college education, and the vast majority ($>90\%$) had annual household incomes of at least \$40,000. Additionally, 73.7% of teens reported living with both their mother and their father, and of the 266 aggregate families in the study, 6 (2.3%) had parents reporting being divorced at the time of the interview.

Overall, nearly 60% of all study participants reported current household keeping of at least one dog, and approximately one-third of all study participants reported current household keeping of at least one cat (Table 1). Among teens included in the study, 106 (19.1%) reported current household keeping of at least one dog and at least one cat; 223 (40.2%) reported current household keeping of at least one dog and no cats; 80 (14.4%) reported current household keeping of at least one cat and no dogs; and 146 (26.3%) reported current household keeping of neither dogs nor cats.

Table 1 Participant characteristics

	Teens	Mothers	Fathers
<i>n</i>	555	435	298
Mean age (SD) at interview, yr	18.3 (0.5)	47.7 (4.3)	50.1 (4.8)
<i>n</i> (%), White race	523 (94.2%)	415 (95.4%)	282 (94.6%)
Gender			
Female	288 (51.9%)		
Male	267 (48.1%)		
Mean no. of child siblings (SD)	1.8 (1.1)		
Married		387 (89.0%)	285 (95.6%)
Education			
HS/GED or less	526 (94.7%)	93 (21.4%)	39 (13.1%)
Some college	29 (5.3%)	143 (32.9%)	86 (28.8%)
College degree	0 (0.0%)	132 (30.3%)	81 (27.2%)
Postgraduate	0 (0.0%)	67 (15.4%)	92 (30.9%)
Household income			
<\$40,000		37 (8.5%)	10 (3.4%)
\$40,000–80,000		104 (23.9%)	63 (21.1%)
\$80,000–100,000		82 (18.8%)	61 (20.5%)
\$100,000–120,000		72 (16.6%)	51 (17.1%)
\$120,000–140,000		40 (9.2%)	28 (9.4%)
\$140,000–200,000		43 (9.9%)	39 (13.1%)
> \$200,000		28 (6.4%)	22 (7.4%)
Refused/do not know		29 (6.7%)	24 (8.0%)
Teen household composition			
Teen only	37 (6.7%)		
Mother and teen	94 (16.9%)		
Father and teen	15 (2.7%)		
Teen, mother, and father	409 (73.7%)		
Household pet exposure			
≥1 Dog	329 (59.3%)	258 (59.3%)	178 (59.7%)
≥1 Cat	186 (33.5%)	147 (33.7%)	92 (30.9%)

HS = high school; GED = general equivalency degree.

IgE Sensitization

There were no statistically significant associations between household dog keeping and dog sIgE for the teens, their mothers, their fathers, or in the family aggregate subset (Table 2). Likewise, there were no statistically significant associations between current household cat keeping related to cat sIgE for any of the family members or in the family aggregate subset (Table 2).

Self-Reported Allergic Symptoms

Among teens who reported experiencing at least one allergy-related symptom in the presence of a dog, 48.8% reported current household dog keeping, compared with 61.1% of teens who did not report allergy-related symptoms (OR, 0.61; 95% CI, 0.38, 0.97; $p = 0.036$). This OR did not change after adjusting for number of siblings and/or education. For their mothers, their fathers, and in the family aggregate subset, there

were no statistically significant differences between those who did and those who did not report experiencing allergic symptoms when in the presence of a dog.

For the teen and father groups, cat-keeping rates did not significantly differ between those who did and those who did not report experiencing allergic symptoms when in the presence of a cat. In contrast, among mothers reporting allergy-related symptoms when in the presence of a cat, 24.3% reported current household cat keeping, compared with 37.0% of mothers who did not report allergy-related symptoms (OR, 0.55; 95% CI, 0.34, 0.89; $p = 0.015$). This association was not confounded by education, number of child siblings, marital status, and/or household income. Statistically significant differences in current household cat keeping were also apparent in the family aggregate subset, with lower odds of current household cat keeping observed in the cat-

Table 2 Prevalence of household pet exposure by allergic sensitization and symptomatic groups

	Pet sIgE, ≥ 0.35 kU/L				Symptomatic Response to Pet			
	Dog		Cat		Dog		Cat	
	SpIgE ⁺	SpIgE ⁻	SpIgE ⁺	SpIgE ⁻	Yes sx	No sx	Yes sx	No sx
Teens (at 18 yr; $n = 555$)								
Current pet*	n (col %)	n (col %)	n (col %)	n (col %)	n (col %)	n (col %)	n (col %)	n (col %)
Yes	60 (59.4%)	269 (59.2%)	35 (30.7%)	151 (34.2%)	40 (48.8%)	289 (61.1%)	49 (29.2%)	137 (35.4%)
No	41 (40.6%)	185 (40.8%)	79 (69.3%)	290 (65.8%)	42 (51.2%)	184 (38.9%)	119 (70.8%)	250 (64.6%)
Chi-square p value	0.98		0.48		0.036#		0.15	
Mothers ($n = 435$)								
Current pet*								
Yes	33 (66.0%)	225 (58.4%)	26 (38.2%)	121 (33.0%)	35 (64.8%)	223 (58.5%)	27 (24.3%)	120 (37.0%)
No	17 (34.0%)	160 (41.6%)	42 (61.8%)	246 (67.0%)	19 (35.2%)	158 (41.5%)	84 (75.7%)	204 (63.0%)
Chi-square p value	0.31		0.40		0.38		0.015#	
Fathers ($n = 298$)								
Current pet*								
Yes	27 (61.4%)	151 (59.4%)	18 (38.3%)	74 (29.5%)	15 (65.2%)	163 (59.3%)	15 (26.3%)	77 (32.0%)
No	17 (38.6%)	103 (40.6%)	29 (61.7%)	177 (70.5%)	8 (34.8%)	112 (40.7%)	42 (73.7%)	164 (68.0%)
Chi-square p value	0.81		0.23		0.58		0.41	
Aggregate families ($n = 266$)								
Current pet*								
Yes	58 (59.2%)	102 (60.7%)	35 (31.8%)	46 (29.5%)	44 (53.7%)	116 (63.0%)	35 (24.1%)	46 (38.0%)
No	40 (40.8%)	66 (39.3%)	75 (68.2%)	110 (70.5%)	38 (46.3%)	68 (37.0%)	110 (75.9%)	75 (62.0%)
Chi-square p value	0.81		0.68		0.15		0.014#	

*Current pet refers to dog in columns under the heading of "dog" and cat in columns under the heading of "cat."

#Statistically significant result ($p < 0.05$).

sIgE = specific immunoglobulin E.

Table 3 Breakdown of mothers with allergic symptoms to pets by allergy symptom category

Asthma	Rhinoconjunctivitis	Hives	Yes Sx to Dog (<i>n</i> = 52) <i>n</i> (%)	Yes Sx to Cat (<i>n</i> = 111) <i>n</i> (%)
0	0	1	2 (3.7%)	1 (0.9%)
0	1	0	16 (29.6%)	40 (36.0%)
0	1	1	1 (1.9%)	4 (3.6%)
1	0	0	1 (1.9%)	1 (0.9%)
1	0	1	1 (1.9%)	1 (0.9%)
1	1	0	23 (42.6%)	47 (42.3%)
1	1	1	10 (18.5%)	17 (15.3%)

0 = Response of “no” to experiencing at least one symptom belonging to the allergy symptom category when exposed to the pet; 1 = response of “yes” to experiencing at least one symptom belonging to the allergy symptom category when exposed to the pet.

symptomatic family aggregate subset (OR, 0.52; 95% CI, 0.32, 0.86; $p = 0.014$; Table 2). Of the 111 mothers who reported experiencing allergic symptoms when in the presence of a cat, 40 (36.0%) reported having rhinoconjunctivitis-type symptoms and 47 (42.3%) reported having rhinoconjunctivitis-type symptoms plus asthma-type symptoms (Table 3).

IgE Sensitization and Self-Reported Allergic Symptoms

There were no associations found between having both detectable dog sIgE and report of experiencing allergy-related symptoms when in the presence of a dog and current household dog keeping among teens, their mothers, their fathers, or in the family aggregate subset (Table 4). Additionally, current household cat keeping was similar among teens, fathers, and their respective reference groups with both allergic sensitization and report of allergic symptoms. However, there was lower household cat keeping among mothers who had both detectable cat sIgE and reported allergic symptoms in the presence of cats (OR, 0.47; 95% CI, 0.22, 1.00; $p = 0.049$; Table 4). This association was not affected by adjustment for the other covariates. In the family aggregate subset, there was no association, suggesting that the impact of maternal sensitization and the absence of cat keeping were abrogated in this group.

To determine whether the standard IgE cut point of 0.35 kU/L²⁵ used in this analysis masked a graded association between sIgE levels and dog and cat keeping, we subsequently performed an analysis using mean sIgE levels for each family member. Results from these calculations showed that there were no statistically significant differences in mean sIgE levels between those who kept a dog or cat and those who did not keep a dog or cat (all, $p > 0.05$; data not shown).

DISCUSSION

Our results suggest that, in general, current household dog and cat keeping is not associated with family

members' pet-specific sensitization and/or self-report of experiencing allergic symptoms when in the presence of such animals. These results stand in contrast to hypotheses suggesting that observed inverse associations between dog or cat keeping and reduced frequency of sensitization to these pets are because of selective avoidance by sensitized individuals.^{29,30}

Among teens, lower household dog keeping was observed in those who reported experiencing allergic symptoms when in the presence of a dog. However, this result was not replicated when restricting analysis to the subset of subjects with complete data or to teens who both reported experiencing allergic symptoms when in the presence of dogs and had detectable dog sIgE.

Household cat keeping was less likely to occur when mothers reported experiencing allergic symptoms in the presence of cats, which was sustained among the mothers who reported cat allergy symptoms and had detectable cat sIgE, although this association disappeared in the family aggregate subset. It is not evident why self-reported allergic symptoms when in the presence of a cat may have significantly influenced keeping of that pet among mothers but not other family members. Keeping a pet that may trigger allergic symptoms in a family member may reflect various factors that we did not collect in our study including symptom severity, the ability to manage those symptoms and the perceived advantages to keeping the pet despite the symptoms (*e.g.*, companionship). Erwin *et al.*, in a study conducted in New Zealand, reported that among children who were sensitized, living with a cat was associated with lower prevalence of IgE antibody to cat (28% versus 66%; $p < 0.001$) and that these differences did not change even after excluding children whose families had chosen to not keep a cat.³¹

When considering the subgroup of 266 families that had their blood drawn at the same clinic visit, neither dog nor cat keeping was associated with the presence or absence of allergy-related symptoms to these pets in

Table 4 Prevalence of household pet exposure by combined allergic sensitization and symptomatic groups

	Dog		Cat	
	sIgE ⁺ and Yes sx	sIgE ⁻ and/or No sx	sIgE ⁺ and Yes sx	sIgE ⁻ and/or No sx
Teens (18 yr; <i>n</i> = 555)				
Current pet*	<i>n</i> (col %)	<i>n</i> (col %)	<i>n</i> (col %)	<i>n</i> (col %)
Yes	21 (61.8%)	308 (59.1%)	22 (26.5%)	164 (34.8%)
No	13 (38.2%)	213 (40.9%)	61 (73.5%)	308 (65.2%)
Chi-square <i>p</i> value		0.76		0.14
Mothers (<i>n</i> = 435)				
Current pet*				
Yes	14 (60.9%)	244 (59.2%)	9 (20.5%)	138 (35.3%)
No	9 (39.1%)	168 (40.8%)	35 (79.5%)	253 (64.7%)
Chi-square <i>p</i> value		0.88		0.049#
Fathers (<i>n</i> = 298)				
Current pet*				
Yes	7 (58.3%)	171 (59.8%)	10 (32.3%)	82 (30.7%)
No	5 (41.7%)	115 (40.2%)	21 (67.7%)	185 (69.3%)
Chi-square <i>p</i> value		0.92		0.86
Aggregate families (<i>n</i> = 266)				
Current pet*				
Yes	23 (59.0%)	137 (60.4%)	22 (25.6%)	59 (32.8%)
No	16 (41.0%)	90 (39.6%)	64 (74.4%)	121 (67.2%)
Chi-square <i>p</i> value		0.87		0.23

*Current pet refers to dog in columns under the heading of "dog" and cat in columns under the heading of "cat."

#Statistically significant result (*p* < 0.05).

sIgE = specific immunoglobulin E.

any of these family members. The associations were found to persist after adjusting for several demographic variables, including parental education level, household income, marital status, and number of child siblings in the family home. The conclusions culled from subgroup analyses were limited by our inability to determine if all three family members lived in a single home. Furthermore, because of the limited racial and ethnic diversity in our sample, it was not possible to estimate the effects of these factors on the associations of interest.

Much of the existing research on pet-keeping practices among persons with pet-related allergies has come from studies conducted in European countries where pet-keeping rates may differ substantially from those in the United States.^{32–35} In one longitudinal European study³² examining follow-up survey data from individuals at ages 0–4 years, 5–15 years, 20–44 years, and 26–56 years, cat ownership (both continuation and acquisition) was found to be less common in subjects with asthma at 5–15 years than those without childhood asthma, and continuation of dog ownership was found to be less common in those with early asthma, but not to the point of statistical significance. Separately, researchers analyzing a Swedish population-based cohort³³ observed that cats were less com-

monly owned among families with members who had asthma, rhinoconjunctivitis, or a pollen or pet-related allergy.

There are limitations to our study. The present analyses are cross-sectional in design rather than longitudinal; therefore, it was not possible to relate pet-keeping patterns to the timing of allergic sensitization or allergic symptomatology. In addition, for those teens who reported living in the same home as the mother and father (73.7%), we did not have data capturing how often or long they were in the parents' home; thus, those who would be more accurately defined as "transient" visitors, perhaps intermittently living on a college campus or elsewhere, were unaccounted for.³⁰ We also did not collect data on locations inside of the home where the dog or cat was allowed (or for how long). These variables would have enabled a better understanding of the consistency and duration in which family members were exposed to the pet.

It is possible that individuals "outgrew" their symptoms to these pets^{30,31} or had less severe pet-related symptoms over time because of longitudinal allergen exposure and the development of immunotolerance.³⁰ It is also plausible that individuals inaccurately associated allergic symptoms caused by a nonpet source (e.g., cockroach, mold spores, etc.) as being triggered by

household pet exposure or similarly failed to attribute an allergic symptom triggered by exposure to the animal. Additional studies examining longitudinal patterns in pet keeping and sensitization and symptoms are needed to determine how pet-keeping choices are driven by health risk avoidances or non-health-related factors.

In conclusion, detectable IgE to dogs or cats was not associated with a family's current household dog- or cat-keeping tendencies. The effect of mothers' allergic symptoms, when in the presence of cats, that are likely to be IgE-driven, may introduce some bias in studies of household pet exposure and the development of allergic disease in birth cohort studies, although the effect is likely to be small.

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