

Household pet exposure, allergic sensitization, and rhinitis in the U.S. population

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Background: The effect of animal dander exposure on allergic sensitization may be age-dependent. A comparison between the association of the levels of exposure to pet allergen with rhinitis symptoms and allergic sensitization in children and adults is yet to be performed in the U.S. population.

Methods: Cross-sectional study of 3034 adults (age, 20 to 85 years) and 2104 children (age, 6 to 19 years) in the National Health and Nutrition Examination Survey, 2005–2006. Samples of household dust were collected to measure the amounts of indoor allergens in the participants' homes. Self-reported rhinitis was based on symptoms during the past 12 months, and allergen sensitization was defined as a positive response to any of the 19 specific immunoglobulin E (IgE) antigens tested.

Results: Higher levels of exposure to dog dander were associated with a higher prevalence of any allergic sensitization in adults (prevalence ratio [PR] 1.19; 95% confidence interval [CI], 1.01 to 1.39), but a lower prevalence in children

(PR 0.84; 95% CI, 0.73 to 0.96), *p*-interaction by age group 0.02. Cat exposure was associated with an increased prevalence of rhinitis symptoms in adults (PR for the 3rd vs lowest tertile of cat dander concentrations: 1.14; 95% CI, 1.05 to 1.23) but not in children (PR for the 3rd vs lowest tertile of cat dander IgE concentrations: 0.86; 95% CI, 0.70 to 1.07), *p*-interaction 0.01.

Conclusion: Allergic sensitization and symptomatic response to pet dander exposure may vary based on age. Further studies are necessary to assess the mechanisms for these apparent differences. © 2017 ARS-AAOA, LLC.

Key Words:

allergy; rhinitis; pets; allergic sensitization; household dust

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Allergic sensitization is a common predisposing factor for chronic inflammatory diseases of the upper airway, such as allergic rhinitis.¹ The associated upper airway symptoms, such as rhinorrhea, watery or itchy eyes, sneezing, and postnasal drip, are extremely common, affecting as much as 44% of the U.S. population.² Animal dander comprises an important class of inhaled allergens. Exposure to pets, such as cats and dogs, has been linked to increased sensitization to those animals' dander, as well as to other inhaled allergens.³ Conversely, according to the hygiene hypothesis, exposure to various microbial or allergic particles, especially in early childhood, may be protective against future allergic sensitization.⁴

A limited number of studies have looked at the relationship between pet ownership and sensitization to animal allergens. In 1 single-institution Korean study of 401 mostly adult patients, exposure to dogs had a significant association with increased sensitization to dog dander, whereas exposure to cats was not associated with sensitization to dog or cat dander.³ On the other hand, there is also

evidence that early exposure to pet dander may prevent development of atopic disorders.⁵ The data on the effects of pet dander exposure on allergic sensitization has overall been inconclusive.

Reports of associations between pet exposure and allergic sensitization have shown conflicting results, demonstrating protective as well as predisposing results. The exposure may also lead to different outcomes in children as opposed to adults. A comprehensive analysis of the association between exposure to pet dander and allergic sensitization between children and adults is lacking in the current literature. Therefore, the purpose of this study was to examine the relationship between pet dander exposure, allergic sensitization, and rhinitis symptoms in a U.S. nationally representative sample of children and adults.

Subjects and methods

Between 2005 and 2006, the National Health and Nutrition Examination Survey (NHANES) recruited a U.S. nationally representative sample of 12,862 people by using a comprehensive multistage sample design.⁶ Of those selected, 10348 were interviewed and 9950 were examined. Older individuals, Mexican Americans, and black individuals were intentionally oversampled. Therefore, appropriate sample weights were used to obtain weighted regression estimates, and the final results of our analyses are generalizable to the noninstitutionalized U.S. population.⁶ The NHANES protocol was reviewed and approved by the National Center for Health Statistics Institutional Review Board. Written informed consent was given by the participants for their clinical records to be used in a research study.

Study population

For this study, we selected participants ≥ 6 years of age ($n = 8567$). We then excluded participants with missing values for household allergen exposure ($n = 2654$), allergic sensitization ($n = 113$), or rhinitis ($n = 3$), as well as those without information on sex, age, ethnicity, education level, or body mass index (BMI) ($n = 193$). Participants included in the analyses were similar with respect to the main sociodemographic variables when compared with the original sample of those surveyed (data not shown).

Exposure assessment

NHANES 2005–2006 collected information on indoor allergen exposure via a nationally representative sample of household dust, measuring the amounts of 10 indoor allergens and endotoxins. The allergens in dust dataset contained the common indoor allergens, including dog and cat hair (*Canis familiaris*, *Felis domesticus*). The dust samples collected were a combined bed and bedroom floor sample for each subject using a vacuum cleaner with a Mitest Dust Collector (Indoor Biotechnologies, Inc., Charlottesville, VA). The amounts of dog and cat allergen

in household dust were subdivided into tertiles of exposure for statistical analyses.

Outcome assessment

Serum samples were analyzed for 19 allergen-specific immunoglobulin Es (IgEs) (*Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*, cat, dog, cockroach, *Alternaria alternata*, peanut, egg, cow's milk, ragweed, rye grass, Bermuda grass, oak, birch, shrimp, *Aspergillus fumigatus*, Russian thistle, mouse, and rat) using the Pharmacia Diagnostics ImmunoCAP 1000 System (Kalamazoo, MI). The lower limit of detection for each of the allergen-specific IgE antibody tests was 0.35 kU/L. Allergen sensitization was defined as a positive response if the level of any of the 19 specific IgE antigens was above the lower limit of detection (0.35 kU/L). Additionally inhaled allergen sensitization was defined as a positive response to *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*, cat, dog, cockroach, *Alternaria alternata*, ragweed, rye grass, Bermuda grass, oak, birch, *Aspergillus fumigatus*, Russian thistle, mouse, and rat. Food allergen sensitization was defined as a positive response to peanut, egg, cow's milk, or shrimp specific IgEs. Self-reported rhinitis was defined an affirmative reply to the question "during the last 12 months have you had a problem with sneezing, or a runny, or blocked nose when you did not have a cold or the flu?"

Adjustment variables

Questionnaire information included participants' gender, age, education level, and race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, other). Measured height and weight were obtained during the physical exam. Body mass index (BMI) percentiles were calculated in children based on the Centers for Disease Control and Prevention (CDC)'s BMI for age- and sex-specific growth charts, and categorized as normal, overweight, and obese if BMI percentiles were ≤ 84 , 85 to 94, and ≥ 95 , respectively. In adults, BMI was categorized as normal, overweight, and obese based on the following cutoffs: <25 , 25 to 30, and ≥ 30 kg/m².

Statistics

Statistical analyses were performed in STATA version 11.2 statistical software (Stata Corp., College Station, TX) by using the survey (svy) command to account for the complex sampling design and weights in the NHANES. The prevalence of allergic sensitization, inhalant allergen sensitization, food allergen sensitization, and rhinitis was calculated overall and by sex, age, ethnicity, education, and BMI percentiles. Prevalence ratios (PRs) and their 95% confidence intervals (CIs) were estimated from Poisson regression models. Trend testing was performed to evaluate for a relationship between increasing levels of an exposure (measured in tertiles) and the outcome variables. Model 1 adjusted for sex and age, whereas model 2 further adjusted

TABLE 1. Allergic sensitization, self-reported rhinitis, and household dust allergen exposure by participant characteristics in U.S. children and adults*

Characteristics	Total allergy sensitization		Inhalant allergy sensitization		Food allergy sensitization		Rhinitis	
	–	+	–	+	–	+	–	+
Children								
Gender								
Male	48.6	51.4	52.2	47.8	75.2	24.8	73.0	27.0
Female	55.4	44.6	59.6	40.4	80.7	19.3	69.5	30.5
Age	12.4 ± 0.2	12.9 ± 0.3	12.2 ± 0.2	13.1 ± 0.3	12.7 ± 0.2	12.5 ± 0.3	12.5 ± 0.2	13.0 ± 0.2
Ethnicity								
White	55.2	44.8	58.8	41.2	80.6	19.4	69.4	30.6
Black	35.6	64.4	39.0	61.0	66.7	33.3	75.0	25.0
Mexican	50.0	50.0	53.8	46.2	78.3	21.7	79.6	20.4
Other	56.3	43.7	62.2	37.8	77.1	22.9	68.4	31.6
Education								
<HS	50.9	49.1	54.7	45.3	75.4	24.6	81.2	18.8
HS	53.3	46.6	57.7	42.3	80.5	19.5	74.5	25.5
>HS	51.5	48.5	55.2	44.8	77.4	22.6	66.1	33.9
BMI								
Normal	43.3	56.7	50.1	49.9	78.1	21.9	78.5	21.5
Over	53.6	46.4	57.4	42.6	78.8	21.2	69.7	30.3
Obese	50.4	49.6	55.8	44.2	76.8	23.2	75.5	24.5
Adults								
Gender								
Male	51.2	48.8	52.6	47.4	81.5	18.5	66.9	33.1
Female	59.4	40.7	61.3	38.7	88.5	11.5	62.3	37.7
Age	48.7 ± 0.9	43.9 ± 0.6	48.8 ± 0.9	43.6 ± 0.6	46.9 ± 0.8	44.6 ± 0.9	46.5 ± 0.7	46.7 ± 0.8
Ethnicity								
White	57.9	42.1	59.7	40.3	87.3	12.7	61.1	38.9
Black	45.1	54.9	46.6	53.4	75.4	24.6	73.3	26.7
Mexican	55.0	45.0	56.6	43.4	82.7	17.3	75.5	24.5
Other	48.3	51.7	49.7	50.3	81.6	18.4	70.7	29.3
Education								
<HS	60.7	39.3	63.5	36.5	83.9	16.1	73.9	26.1
HS	54.3	45.7	56.1	43.9	85.1	14.9	69.3	30.7
>HS	54.2	45.8	55.5	44.5	85.5	14.5	58.9	41.1
BMI								
Normal	54.6	45.4	55.1	44.9	86.5	13.5	65.4	34.6
Over	56.1	43.9	58.2	41.8	85.4	14.6	66.6	33.4
Obese	55.7	44.3	58.0	42.0	83.7	16.4	61.5	38.5

*Values are percentages or means ± standard deviations.
 BMI = body mass index; HS = high school.

TABLE 2. Association between rhinitis and pet dander exposure by household dust particle tertile*

Pet dander exposure	Rhinitis symptoms							
	Children			Adults			<i>p</i> -interaction ^a	
	<i>n</i>	Model 1	Model 2	<i>n</i>	Model 1	Model 2	Model 1	Model 2
Dog dander tertile								
1	703	1	1		1	1		
2	700	1.06 (0.79–1.44)	0.96 (0.73–1.26)	1007	1.22 (1.02–1.46)	1.13 (0.93–1.37)		
3	701	1.13 (0.86–1.49)	0.94 (0.75–1.18)	1011	1.35 (1.09–1.69)	1.20 (0.94–1.52)		
<i>p</i> -trend		0.37	0.63		0.01	0.14	0.59	0.30
Cat dander tertile								
1	703	1	1	1017	1	1		
2	700	1.07 (0.86–1.34)	0.93 (0.77–1.12)	1006	1.25 (1.03–1.53)	1.16 (0.94–1.43)		
3	701	1.04 (0.84–1.28)	0.86 (0.70–1.07)	1011	1.32 (1.20–1.44)	1.14 (1.05–1.24)		
<i>p</i> -trend		0.85	<0.01		<0.01	0.14	0.05	0.01

*Values are prevalence ratio estimates (95% confidence intervals) except as indicated. Model 1 adjusted for sex and age. Model 2 adjusted sex, age, ethnicity, education, and BMI.

^a*p*-interaction for the effect of the age category on the association between pet exposure and rhinitis.

BMI = body mass index.

for ethnicity, education, and BMI. Interaction terms were estimated to assess whether the associations were significantly different for children (6 to 18 years) and adults (>18 years). As a sensitivity analysis, groups were further stratified by smoking exposure and older and younger pediatric age groups, without significant changes in findings. Therefore, those analyses were excluded from the study.

Results

A total of 5138 individuals were included in the study: 2104 children and 3034 adults. As shown in Table 1, 51.4% of male and 44.6% female children were sensitized to at least 1 allergen and 27% of male and 30.5% of female children self-reported as having rhinitis. Black children had the highest prevalence of sensitization, whereas children with the highest level of household education had the highest prevalence of rhinitis. Among adults, 48.8% of males and 40.7% of females were sensitized to at least 1 allergen and 33.1% of males and 37.7% of females self-reported rhinitis. Black adults had the highest prevalence of sensitization, whereas white adults, and adults with higher education levels showed a higher prevalence of rhinitis.

Results for the association between dog and cat exposure and rhinitis symptoms in children and adults are shown in Table 2. Adults, but not children, showed a significant association between higher levels of dog (3rd tertile PR 1.35; 95% CI, 1.09 to 1.69). In children, a significant trend was observed between increasing cat dander exposure and a decrease in rhinitis symptoms ($p < 0.01$). When comparing the tertiles of exposure, cat exposure was associated with an increased prevalence of rhinitis symptoms in adults (PR for the 3rd vs lowest tertile of cat dander

concentrations: 1.14 [95% CI, 1.05 to 1.23]), but not in children (PR for the 3rd vs lowest tertile of cat dander IgE concentrations: 0.86 [95% CI, 0.70 to 1.07]), *p*-interaction 0.01.

The results for the association between allergic sensitization and dog and cat exposure in children and adults are shown in Table 3. The adjusted PRs (95% CI) of total allergen sensitization comparing the second and third tertiles to the lowest tertile of dog dander concentrations in dust were: 0.97 (95% CI, 0.84 to 1.12) and 1.19 (95% CI, 1.01 to 1.39) in adults, and 0.83 (95% CI, 0.71 to 0.96) and 0.84 (95% CI, 0.73 to 0.96) in children (*p*-interaction by age group: 0.02). Similarly, the adjusted PRs of inhaled allergen sensitization comparing the second and third tertiles to the lowest tertile of dog dander concentrations were: 0.97 (95% CI, 0.82 to 1.13) and 1.20 (95% CI, 1.02 to 1.41) in adults, and 0.84 (95% CI, 0.70 to 1.01) and 0.86 (95% CI, 0.74 to 1.00) in children (*p*-interaction by age: 0.04). The adjusted PRs (95% CI) of total allergen sensitization comparing the second and third tertiles to the lowest tertile of cat dander concentrations in dust were: 1.05 (95% CI, 0.94 to 1.17) and 0.92 (95% CI, 0.79 to 1.09) in adults, and 0.99 (95% CI, 0.83 to 1.20) and 0.89 (95% CI, 0.70 to 1.12) in children (*p*-interaction by age group: 0.86). Similarly, the adjusted prevalence ratios of inhaled allergen sensitization comparing the second and third tertiles to the lowest tertile of cat dander concentrations were: 1.07 (95% CI, 0.94 to 1.23) and 0.94 (95% CI, 0.79 to 1.12) in adults, and 1.00 (95% CI, 0.83 to 1.22) and 0.90 (95% CI, 0.73 to 1.11) in children (*p*-interaction by age: 0.72). Increasing exposure to dog dander was associated with a significant trend to increasing prevalence of allergic sensitization to dogs in adults but not in children. No significant

TABLE 3. Association between allergic sensitization and pet dander exposure by household dust particle tertile*

	n	Any allergic sensitization		Inhaled allergic sensitization		Food allergic sensitization	
		Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Children (n = 2104)							
Dog dander							
1st tertile	703	1	1	1	1	1	1
2ndtertile	700	0.76 (0.65–0.88)	0.83 (0.71–0.96)	0.76 (0.62–0.93)	0.84 (0.70–1.01)	0.69 (0.52–0.91)	0.78 (0.58–1.06)
3rd tertile	701	0.75 (0.66–0.85)	0.84 (0.74–0.96)	0.75 (0.64–0.89)	0.86 (0.74–1.00)	0.63 (0.47–0.83)	0.74 (0.52–1.05)
p-trend		<0.01	0.05	<0.01	0.11	<0.01	0.1
p-interaction ^a		<0.01	0.02	0.02	0.04	0.04	0.09
Cat dander							
1st tertile	703	1	1	1	1	1	1
2ndtertile	700	0.90 (0.77–1.05)	0.99 (0.83–1.20)	0.90 (0.76–1.06)	1.00 (0.83–1.22)	0.85 (0.66–1.10)	0.96 (0.75–1.25)
3rd tertile	701	0.77 (0.64–0.93)	0.89 (0.70–1.12)	0.77 (0.65–0.91)	0.90 (0.73–1.11)	0.59 (0.39–0.89)	0.70 (0.44–1.11)
p-trend		0.01	0.24	<0.01	0.2	0.01	0.1
p-interaction ^a		0.69	0.86	0.53	0.72	0.73	0.74
Adults (n = 3034)							
Dog dander							
1st tertile	1016	1	1	1	1	1	1
2ndtertile	1007	0.92 (0.80–1.04)	0.97 (0.84–1.12)	0.91 (0.79–1.05)	0.97 (0.82–1.13)	0.82 (0.64–1.05)	0.95 (0.73–1.23)
3rd tertile	1011	1.10 (0.97–1.26)	1.19 (1.01–1.39)	1.11 (0.98–1.26)	1.20 (1.02–1.41)	0.88 (0.71–1.09)	1.09 (0.85–1.39)
p-trend		0.06	0.02	0.03	<0.01	0.31	0.38
p-interaction ^a		<0.01	0.02	0.02	0.04	0.04	0.09
Cat dander							
1st tertile	1017	1	1	1	1	1	1
2ndtertile	1006	1.02 (0.91–1.14)	1.05 (0.94–1.17)	1.04 (0.91–1.20)	1.07 (0.94–1.23)	0.90 (0.66–1.21)	1.02 (0.72–1.43)
3rd tertile	1011	0.88 (0.74–1.04)	0.92 (0.79–1.09)	0.89 (0.75–1.07)	0.94 (0.79–1.12)	0.69 (0.54–0.89)	0.84 (0.64–1.11)
p-trend		0.1	0.23	0.15	0.33	0.05	0.16
p-interaction ^a		0.69	0.86	0.53	0.72	0.73	0.74

*Values are prevalence ratio estimates (95% confidence intervals). Model 1 adjusted for sex and age. Model 2 adjusted sex, age, ethnicity, education, and BMI.

^a*p*-interaction for the effect of the age category on the association between pet exposure and allergic sensitization.

BMI = body mass index.

association was observed between cat dander exposure and allergic sensitization to cats in adults or children (data not shown).

Discussion

This study evaluated the association between exposure to dog and cat dander in household dust and the prevalence of rhinitis and allergic sensitization in U.S. children and adults. The prevalence of rhinitis in our cohort was consistent with previous reports using NHANES data^{7,8} as well as with other U.S. nationwide surveys.² The assessment of

household allergen exposure in this study is highly sensitive and this method of exposure has been described in the literature.⁹ The data showed a higher prevalence of allergic sensitization and rhinitis symptoms in adults exposed to greater amounts of dog dander. Children, on the other hand, showed a lower prevalence of allergic sensitization associated with greater dog dander exposure, and no difference in rhinitis symptoms. For cat exposure, there was a higher prevalence of rhinitis symptoms in adults with greater levels of exposure, without a significant difference in allergic sensitization. Cat dander exposure was not associated with allergic sensitization or rhinitis symptoms in children.

Associations between household pets and allergic disease have been analyzed in the literature, with conflicting results. Significant associations have been observed between dog exposure and higher levels of allergic sensitization.³ Along with the allergic sensitization, dog exposure has also been observed to have a possible link to increased allergy-related upper respiratory diseases, such as allergic rhinitis and asthma.¹⁰ Likewise, cat ownership has been associated with an increased prevalence of upper respiratory conditions such as asthma.¹¹ On the other hand, there are numerous reports of a lower prevalence of allergic diseases in individuals living with pets.^{12–14} A potentially protective effect of pet exposure against allergic sensitization has also been observed with both cats and dogs. To complicate matters further, other studies have found no association between pet exposure and allergic disease.¹⁵ This variability in results has created a high level of uncertainty in the literature on the relation between pet exposure and allergic disease.

An important factor that may determine the direction of the associations between pet dander and allergic disease is the age at exposure. Based on the hygiene hypothesis, early-life exposure to certain antigens may be protective against sensitization later in life.¹⁶ Recent work looking at the relationship between endotoxin exposure and allergic sensitization has provided support for this hypothesis. A component of the outer membrane of gram-negative bacteria ubiquitous in the environment, endotoxin has a strong pro-inflammatory property that can trigger cytokine release.¹⁷ In a recent large study using the NHANES database, increasing exposure to endotoxin was observed to be associated with a reduced risk of allergic sensitization in children and adolescents. In adults, on the other hand, increasing endotoxin exposure was associated with increased allergic sensitization.⁹ In terms of pet exposure, there has also been evidence that living with a cat and a dog at an early age may be protective against later development of atopy.^{18,19} A possible mechanism for this protective effect has been proposed, with the possibility that high exposure to an allergen might protect from sensitization to that allergen later

in life via a modified T helper 2 (Th2) response.²⁰ This age-dependent effect may explain some of the inconsistencies in the associations between pet exposure and allergic disease in the literature.

The strengths and limitations of our study should be considered. This study was cross-sectional, and therefore temporality with respect to exposure variables cannot be determined. As a consequence of the cross-sectional design, reverse causation may also play a role, as individuals with diagnosed allergic disease may try to limit their pet exposure. Also, for adults, there is no data on childhood pet exposure, and so there is no opportunity to compare the findings for adults with and without pets during childhood. On the other hand, data from NHANES are comprehensive and nationally representative, drawing from a large sample of participants. The NHANES household dust measurements as well as the assessments of allergic sensitization are high-quality objective measures of exposure and outcome that have been shown to be reliable in past studies.^{9,21,22} In this study, rhinitis was self-reported, and so the assessment may be prone to recall bias, although it is unlikely that those with different amounts of exposure would differ in their recall abilities. Although multivariable adjustments were used in the analyses, there is also the possibility of residual confounding by unmeasured factors.

Conclusion

This study showed that pet dander exposure may be associated with opposite effects on allergic sensitization and rhinitis symptoms in children and adults. Adults with greater exposure to dog and cat dander had a significantly higher prevalence of rhinitis symptoms, whereas those with greater dog exposure had more allergic sensitization. In children, on the other hand, dog dander exposure was associated with a lower prevalence of allergic sensitization. This age-dependent association adds further evidence to the hygiene hypothesis, suggesting possible protection against sensitization with early allergen exposure. Longitudinal data is needed to further define these relationships. 🌐

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