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Age-Specific Prevalence of Outdoor and Indoor Aeroallergen Sensitization in Boston

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Abstract

Questions exist regarding the appropriate age for referral of an atopic child to an allergist for environmental skin prick testing. This study evaluates age-specific prevalence of sensitization to aeroallergens from infancy through adolescence. A total of 1394 patients were skin tested, with 57.2% being sensitized to at least 1 aeroallergen. In children younger than 2, the authors found that 26.5% were sensitized, including to dogs (15.5%) and cats (9.2%). Additionally, tree sensitization was demonstrated in the youngest age group (7.8% at 0–2 years; 17.1% at 2–4 years), including in 3 infants less than 1 year old. Sensitization rates to dust mites and trees were the highest in all ages above 4 years, with a peak tree sensitization of 56.4% at 10 to 12 years and a peak dust mite sensitization of 56.8% in the >12 group. Overall, the authors observed increasing sensitization rates throughout childhood for indoor and outdoor aeroallergens ($P < .001$). Aeroallergen sensitization begins at a young age and increases during childhood.

Keywords

allergy; skin prick test; children; atopy

Introduction

The prevalence of asthma, allergic rhinitis, and atopic dermatitis has risen over the past several decades.^{1–5} These chronic illnesses account for a substantial proportion of pediatric primary care visits. Sensitization to environmental allergens is a major risk factor for the development of these conditions and is associated with increased morbidity. It has been shown that more than 50% of children with wheezing⁶ and more than 75% of children with rhinitis⁷ are sensitized to aeroallergens. Early identification of specific environmental allergies in children may assist in medical and environmental interventions in disease management.

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Skin prick testing (SPT) is the main diagnostic tool used to evaluate environmental allergy sensitization. This method has superior sensitivity and positive predictive value when compared with specific IgE blood testing.⁸ Primary care providers must decide when it is appropriate to refer a child to an allergist for further evaluation and possible skin testing. This decision is often based on symptom severity. Additionally, age is an important factor. It is commonly recommended that practitioners delay referral for SPT, particularly to outdoor aeroallergens, until later in childhood.⁹

The purpose of this study was to perform an analysis of aeroallergen sensitization rates for patients who have been referred to our pediatric allergy program for SPT, specifically focusing on infants and younger children. Most previous studies on sensitization have focused on older children (>6 years). Our objective was to provide further evidence to assist primary care physicians who are considering referring a young patient for allergy evaluation.

Methods

This study was a retrospective analysis of our skin test database over a 15-month period (October 2006 to December, 2007). The study was approved by the Institutional Review Board of Children's Hospital Boston. All patients referred to the Children's Hospital Boston Allergy and Immunology program who had SPT to at least 1 aeroallergen were included.

SPT to commercially available extracts (Greer Laboratories, Lenoir, NC; and Hollister-Stier, Spokane, WA) was performed on the back or volar surface of the forearm with the Multitest applicator (Lincoln Diagnostics, Inc, Decatur, IL) using standard methods.¹⁰ Aeroallergens included trees (birch, oak, maple, or elm), grass mix (kentucky blue, orchard, red top, timothy, and sweet vernal grass), ragweed mix (giant and short ragweed), dust mites (*Dermatophagoides farinae* allergen 1 [Der f 1], *Dermatophagoides pteronyssinus* allergen 1 [Der p 1]), cockroaches, dogs, cats, and mice. Positive histamine and negative saline controls were used. A wheal 3 mm greater than the negative control at 15 minutes was considered positive. This method has been shown to be useful in children as young as 3 months of age.¹¹ Medications that might interfere with skin testing were withheld prior to skin testing (immediate antihistamines for 3 days, long-acting antihistamines for 10 days, and cetirizine for 14 days). Patients were excluded if they had a negative histamine control.

Statistics

Patients were tested to as many of these aeroallergens as clinically indicated by their allergist. Eight patients were skin tested on 2 occasions at different ages during the study period, and each testing visit was entered as an individual patient. Sensitivity to a specific aeroallergen was defined by a positive skin test. Prevalence rates of sensitization for each allergen in all age groups were calculated. Prevalence rates among groups were compared by performing a Pearson χ^2 analysis.

Results

Age-Specific Rates of Sensitization

There were a total of 1394 participants in our study, with 817 (58.6%) being male. The ages ranged from 4 months to 21 years, with a median age of 5.5 years. The patients were divided into the following age groups: 0 to 2 years (n = 204), 2 to 4 years (n = 301), 4 to 6 years (n = 235), 6 to 8 years (n = 195), 8 to 10 years (n = 153), 10 to 12 years (n = 117), and greater than 12 years (n = 189). The majority (53.1%) of our participants were less than 6 years old. The number of skin prick tests performed on each participant ranged from 1 to all 8 of the studied aeroallergens; 1381 (99.1%) of the patients were tested to at least 1 of the studied indoor aeroallergens (mouse, cockroach, dog, cat, and dust mites), whereas 1222 (87.7%)

were tested to at least 1 of the studied outdoor aeroallergens (tree, grass, ragweed); 1081 (77.5%) of the participants were tested to all 8 aeroallergens.

Analysis of all age groups revealed that 57.2% of the patients were positive on SPT to at least 1 of the studied aeroallergens. Age-specific sensitization rates ranged from 26.5% in the youngest age group (0–2 years) to a peak of 81.2% in the 10 to 12 age group (Table 1). Overall, there were increasing sensitization rates to at least 1 aeroallergen throughout childhood ($P < .001$). Additionally, odds ratios of sensitization increased throughout childhood when comparing age-specific sensitization to sensitization in the youngest age group (0–2 years), as demonstrated in Table 1. Although there was a decrease in sensitization rate in the oldest group (72.5%) compared with the 10 to 12 age group (81.2%), this difference was not statistically significant ($P = .084$). The rate of sensitization in children less than 6 years of age was 43.8% (324 sensitized/740 tested) compared with a rate of 72.5% (474 sensitized/654 tested) in patients older than 6.

In total, 51.3% of those tested were sensitized to at least one of the indoor allergens, whereas 38.8% of those tested to outdoor allergens were positive. Sensitization to any indoor allergen increased from 23.9% in the youngest group to a peak of 73.5% in the 10 to 12 year old age group (Figure 1). Likewise, Sensitization to any outdoor allergen increased from 9.5% in the 0 to 2 age group to a maximum of 64.0% in the 10 to 12 age group. Overall, we observed increasing sensitization rates throughout childhood to at least 1 indoor aeroallergen ($P < .001$) and similarly to at least 1 outdoor aeroallergen ($P < .001$).

Age-specific sensitization rates to each individual aeroallergen are presented in Table 2. In the youngest children, dogs (15.5% at 0–2 years) and cats (22.5% at 2–4 years) were the most common sensitizers. Dust mites and trees became the most prevalent sensitizers in all the greater-than-4 age groups, with peaks of 56.8% for dust mites (>12 years) and 56.4% for trees (10–12 years). Additionally, trees (35.8%) and dust mites (35.6%) were the most prevalent when all ages were combined. Cats were the most prevalent animal sensitizers (31.3%).

Grass and ragweed were the least common sensitizers in younger children, with rates of 1.0% (0–2 years) and 2.8% (2–4 years) for grass and 1.0% (0–2 years) and 5.7% (2–4 years) for ragweed. However, these aeroallergens became more prevalent in the older age groups, with rates of 28.8% for grass and 34.2% for ragweed at 10 to 12 years of age. Mice were the least prevalent sensitization overall (8.8%) and in all ages greater than 8 years.

Aeroallergen Sensitization in Young Children

SPT in the youngest children yielded interesting results. The youngest ages at which a participant was sensitized to indoor allergens were as follows: dogs (4 months), cats (6 months), dust mites (9 months), mice (11 months), and cockroaches (16 months). The youngest ages at which a participant was sensitized to outdoor allergens were as follows: trees (11 months), grass (13 months), and ragweed (23 months). In contrast to other outdoor aeroallergens, tree sensitization occurred earlier and was much more common in younger children, with rates of 7.8% at 0 to 2 years and 17.1% at 2 to 4 years. Three children younger than 12 months were found to be sensitized to tree pollen. Overall, 15 (31.3%) of the 48 infants less than 1 year of age who were tested were found to be sensitized to at least 1 of the aeroallergens.

Gender-Specific Rates of Sensitization

Boys ($n = 816$) were skin prick tested more often than girls ($n = 577$) during our study period. Additionally, the former were more likely to be sensitized to any allergen as compared to the latter (60.1% vs 53.2%; $P = .010$). Boys had higher rates of sensitization for

every age group, but significant differences were noted in the 4 to 6 age group (62.5% vs 47.3%; $P = .022$) and the 10 to 12 age group (90.8% vs 69.2%; $P = .003$). Boys were also more likely to be sensitized to any indoor aeroallergen (53.5% vs 47.6%; $P = .023$) and any outdoor aeroallergen (41.3% vs 35.4%; $P = .037$). Individual analyses demonstrated higher sensitization rates in boys for every aeroallergen, but significant differences were noted for dogs (26.6% vs 20.5%; $P = .012$), grass (14.7% vs 9.2%; $P = .004$), and ragweed (20.6% vs 13.6%; $P = .002$). Dust mite was the aeroallergen to which boys and girls were most similarly sensitized (35.8% vs 35.3%; $P = .846$).

Discussion

This study provides the prevalence of aeroallergen sensitization in a subset of referred children with presumed atopic disease. The majority of our participants were young children as we had 740 patients younger than 6 and, thus, the largest cohort for determining aeroallergen sensitization rates in this age group. Our study is unique because it includes data from young children, in addition to older children and adolescents. The primary finding of our study was the increase in rates of sensitization to indoor and outdoor aeroallergens throughout childhood. We also found different aeroallergens to be prominent at different ages. For example, dogs and cats were the most likely sensitizers in children younger than 4, whereas dust mites and trees were the most prominent in older children and adolescents. It is commonly thought that young children are not sensitized to outdoor aeroallergens. An unexpected finding was the relatively high rate of tree sensitization in the youngest children. Our data provide pediatricians with further information when considering referral of a patient for an allergy evaluation.

Overall, we found that 57.2% of the referred patients who underwent SPT were sensitized to at least 1 of the studied aeroallergens. Also, 51.3% of patients were sensitized to at least 1 indoor aeroallergen, and 38.8% were sensitized to at least 1 outdoor aeroallergen. Table 3 lists the result of similar studies on SPT sensitization. For this table, studies with pediatric patients performed in the United States in the past 20 years were included. Our rates are similar to those found in other studies of sensitization in children at risk for atopy. The most similar study for our overall age range was performed in New York City among children with asthma aged 1 to 18.¹² In this study of 384 inner-city Hispanic and African American children, 58.6% were sensitized to at least 1 indoor allergen, and 28.4% were sensitized to an outdoor allergen. Calabria and Dice¹³ reviewed pediatric patients with rhinitis and reported that 35.4% of children younger than 6 and 80.3% of patients aged 3 to 18 were sensitized.

There are larger studies available on sensitization prevalence in children older than 6 because of the data provided by the National Health and Nutrition Examination Surveys (NHANES II and III). Arbes et al¹⁴ have reported that 54.0% of the responders were positive on SPT to 1 of the 9 aeroallergens (peanut excluded) tested in NHANES III. This analysis included more than 10 000 participants aged 6 to 59 years from the general US population. From the same NHANES III data, von Mutius and colleagues¹⁵ reported that 52.3% of children aged 6 to 17 years were sensitized to at least 1 common aeroallergen. Similarly, a study of Brazilian adolescents demonstrated that 48.6% of the general public was sensitized.¹⁶ The Tuscon Children's Respiratory Study demonstrated longitudinal sensitization rates of 38.6% at 6 years of age and 58.1% at 11 years of age.¹⁷ Compared with these studies in the general population, our study showed higher rates, with 72.5% of patients older than 6 being sensitized, including 67.2% at 6 to 8 years and 81.2% at 10 to 12 years. Our prevalence rates are similar to other studies of higher-risk patients.^{7,12,13,18} A higher prevalence is expected as our study was in a referral population with presumed atopy.

Accordingly, our study is more reflective of the atopic pediatric population in which pediatricians are considering an allergy referral.

Few studies report sensitization rates in young children. Our analysis of younger children demonstrated that 26.5% younger than 2 and 43.8% younger than 6 were sensitized. Higher rates have been seen in other studies enrolling only children at higher risk for atopy. LeMasters et al¹⁹ reported longitudinal aeroallergen sensitization rates of 18.0% at age 1 and 36.3% at age 2 in a cohort of infants of atopic parents.¹⁹ The Prevention of Early Asthma in Kids (PEAK) study evaluated a cohort of 3-year-old children with recurrent wheezing and discovered that 54% were sensitized to at least 1 aeroallergen.⁶ It is likely that our study underestimates the true prevalence of sensitization in these younger children because not all our young children were tested to all aeroallergens. For example, 12.3% of our total study (including 21.4% of children younger than 6) were not tested to any outdoor allergens. Additionally, many young patients were only tested to a select number of indoor allergens. It is possible that if all the patients in our study had been tested to all the analyzed aeroallergens, our prevalence rates might have been higher, especially in younger children.

As expected, the outdoor allergens experienced dramatic increases during middle childhood. Specifically, this increase was most notable in the transition from the 2 to 4 age group to the 4 to 6 age group. In this transition, there was more than a doubling of the rates for every outdoor allergen, including trees (17.1% to 35.3%), grass (2.8% to 9.3%), and ragweed (5.7% to 17.9%). None of the rates for indoor allergens doubled during this time period. Grass and ragweed showed the most dramatic increases, with almost nonexistent rates in the 0 to 2 age group (1.0% for each), to the fourth (ragweed, 34.2%) and fifth (grass, 28.8%) most common allergens in the 10 to 12 age group. These data correspond with previous recommendations encouraging indoor allergen testing in younger individuals and the addition of outdoor allergen testing later in childhood.⁹

We found relatively high rates of tree allergy in children younger than 4 years old. Rates of 7.8% in the 0 to 2 age group and 17.1% in the 2 to 4 age group are high enough to warrant consideration of skin testing to trees at these young ages. Whereas Calabria and Dice¹³ reported that only 4% of rhinitis patients less than 3 years old were sensitized to seasonal aeroallergens, our study demonstrated higher rates for outdoor aeroallergens. Our data are more in concordance with those of LeMasters et al¹⁹ who found that 9.7% of at-risk 1-year-olds were sensitized to pollen (grass, ragweed, tree). Similarly, Ogershok et al²⁰ described high rates of pollen sensitization with 29% of 1- to 2-year-olds and 40% of 2- to 3-year-olds being sensitized to at least one outdoor pollen (tree, grass, or ragweed). However, this study was based on a small number of young children (98 patients less than 3 years old) and did not report any children younger than 12 months being sensitized to tree pollen. A surprising result of our study was the presence of tree pollen sensitization in infants less than 12 months old (3 positive of 12 participants tested). Selection bias may be an important factor in this very young group because only 12 patients younger than 12 months of age were skin tested to trees. It is expected that these children were tested because of a particularly suspicious clinical history because it is not common to test infants for tree sensitization. When comparing different aeroallergens, our population showed a higher rate of sensitization to trees compared with certain indoor allergens, such as cockroaches and mice, at all age groups, including the youngest of children. These points further underscore the importance of considering skin testing to trees in young children, even those younger than 12 months with allergic symptoms during the spring months.

It was noteworthy that in our referred population, boys had higher rates of sensitization as compared with girls. Previous studies have established that male participants have more atopy compared with female participants when selected from the general public.¹⁴ However,

other studies have shown similar sensitization rates between male and female participants in higher-risk populations, such as allergic rhinitis patients⁷ and asthmatic patients.¹⁸ Our study group was entirely composed of referred patients where both boys and girls had presumed atopy. Despite this, we found boys to have a significantly higher prevalence of sensitization to indoor and outdoor aeroallergens. This finding is similar to that of the PEAK study, which noted that male children were significantly more likely to be sensitized to aeroallergens.⁶

This study is limited by a retrospective design. As is inherent in such a study, not all patients received the same testing. Of the 1394 patients included in the study, 1081 (77.5%) had complete testing to all 8 of the analyzed allergens. In the other 22.5%, at least one of the allergens was excluded from skin testing as clinically indicated. Sensitization rates to trees might be most affected by these exclusions. In the youngest of children, outdoor allergens are often not tested because of the perceived low pretest probability. For example, 50% of our analyzed patients less than 2 years of age (and 75.0% of patients less than 1 year) were not skin tested to trees. It would be interesting to see the prevalence rates of tree sensitization if all the younger children are tested. Second, it would be beneficial to obtain information on clinical symptoms. We know that all patients were referred to our center for evaluation of possible atopic illnesses; however, we do not have any more specific information on clinical symptoms. Finally, it is important to note that tree pollen exposures vary in different climates. Our patients are representative of New England. It is expected that warmer climates would have more pollen exposure and possibly higher sensitization rates.

In conclusion, we had sufficient data to show the increasing prevalence rates of aeroallergen sensitization throughout childhood in a large referral population. Our study demonstrates that cats, dogs, and dust mites are the predominant sensitizers in younger children, whereas trees and dust mites are the most prevalent sensitizers in older children and adolescents. In contrast to grass and ragweed, tree sensitization is much more common than expected in very young children. This finding warrants more consideration of testing for tree allergy in infants and toddlers. Overall, we have provided further information for physicians considering referrals for SPT and guidance on allergen avoidance. These data are especially useful in the youngest children with allergy and asthma symptoms.

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Figure 1. Age-specific prevalence of sensitization^a

▲, Sensitization to at least 1 of the aeroallergens studied; ●, sensitization to at least 1 of the indoor aeroallergens (cats, dogs, dust mites, mice, cockroaches); ■, sensitization to at least 1 of the outdoor aeroallergens (trees, grass, ragweed).

Table 1

Prevalence of Positive SPT for Any Allergen for All Ages

Age Group (years)	Participants (Number Tested)	Percentage Sensitized (1 Positive Test)	Odds Ratio (95% CI)
0–2	204	26.5	1.0 (Reference)
2–4	301	45.5	2.3 (1.6 – 3.4)
4–6	235	56.6	3.6 (2.4 – 5.4)
6–8	195	67.2	5.7 (3.7 – 8.8)
8–10	153	72.5	7.3 (4.6 – 11.8)
10–12	117	81.2	12.0 (6.9 – 21.0)
> 12	189	72.5	7.3 (4.7 – 11.4)
Total	1394	57.2	

Abbreviations: SPT, skin prick test; CI, confidence interval.

Table 2

Prevalence of Positive Skin Prick Test for Each Allergen (All Ages)^a

Age (years)	Indoor Allergens					Outdoor Allergens		
	Mice	Roaches	Dogs	Cats	Mites	Trees	Grass	Weeds
0-2	3.2 (93)	3.6 (138)	15.5 (174)	9.2 (174)	8.2 (195)	7.8 (103)	1.0 (98)	1.0 (97)
2-4	8.1 (235)	10.9 (239)	21.0 (271)	22.5 (267)	22.3 (287)	17.1 (252)	2.8 (246)	5.7 (245)
4-6	8.3 (206)	8.8 (205)	25.0 (216)	33.3 (222)	37.2 (231)	35.3 (221)	9.3 (215)	17.9 (218)
6-8	10.9 (184)	14.2 (183)	31.1 (190)	37.0 (189)	41.9 (191)	46.6 (191)	10.1 (189)	20.9 (187)
8-10	5.6 (142)	15.8 (139)	28.4 (148)	41.1 (146)	47.9 (140)	46.6 (148)	19.6 (143)	23.6 (144)
10-12	13.5 (111)	19.8 (111)	26.5 (113)	48.2 (110)	53.1 (113)	56.4 (110)	28.8 (111)	34.2 (111)
> 12	10.4 (182)	22.2 (180)	23.0 (187)	38.5 (187)	56.8 (185)	45.2 (188)	21.7 (184)	24.3 (185)
Total	8.8 (1153)	13.3 (1195)	24.0 (1299)	31.3 (1295)	35.6 (1342)	35.8 (1213)	12.4 (1186)	17.7 (1187)

^a Percentages are reported with total number tested in parentheses.

Summary of Previous Studies of Aeroallergen Sensitization Prevalence (Pediatric Studies, 1988–2008, United States)

Table 3

Reference	Location	Study Design	Participant Selection	Age (years)	Number	Aeroallergens Tested	Percentage Sensitized (to at Least 1 Allergen)
Current study	Boston, MA	Cross-sectional/Retrospective	Allergy referral	0–5	740	D, C, DM, Co, M, P	43.8
Previous studies							
LeMasters et al ¹⁹	Cincinnati, OH	Longitudinal/ Prospective	Parents with atopy	1	680	D, C, DM, P, Mo	18.0
Guilbert et al ⁶	United States (Multiple Cities)	Cross-sectional/Prospective (PEAK study)	Recurrent wheeze	2	589	D, C, DM, P, Mo	36.3
Calabria and Dice ¹³	San Antonio, TX	Cross-sectional/Retrospective	Rhinitis	2–3	244	D, C, DM, Co, P, Mo	54.1
Stern et al ¹⁷	Tucson, AZ	Longitudinal/(TCRS study) Prospective	General	0–6	209	D, C, DM, Co, P, Mo	35.4
Arbes et al ¹⁴	United States (multiple cities)	Cross-sectional/ Prospective (NHANES III study)	General	3–18	345	D, C, DM, Co, M, R, F, P, Mo	80.3
Rastogi et al ¹²	New York, NY	Cross-sectional/Retrospective	Asthma	6	761	Du, P, Mo	38.6
				11	709	C, DM, P, Mo	58.1
				6–9	1869	C, DM, Co, P, Mo (and peanuts)	45.6
				10–19	3789	C, DM, Co, P, Mo (and peanuts)	55.5
				1–18	384	D, C, DM, Co, M, P, Mo	58.6 (Indoor); 28.4 (Outdoor)

Abbreviations: D, dog; C, cat; DM, dust mite; Du, house dust mix; Co, cockroach; M, mouse; P, pollen (tree, grass, and ragweed); Mo, mold; R, rat; F, feather; PEAK, Prevention of Early Asthma in Kids; TCRS, Tucson Children's Respiratory Study; NHANES, National Health and Nutrition Examination Surveys.