

Ethnicity and Skin Test Reactivity to Aeroallergens Among Asthmatic Children in Connecticut*

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Objectives: To examine the relationship between ethnicity and sensitization to allergens among children with asthma living in urban and suburban areas of Connecticut.

Study design: Cross-sectional study.

Study population: A total of 791 children with mild-to-severe asthma who received their medical care in the city of Hartford.

Results: Puerto Rican ethnicity was associated with skin test reactivity (STR) to cockroach (odds ratio [OR], 3.3; 95% confidence interval [CI], 1.7 to 6.4), STR to dust mite (OR, 1.7; 95% CI, 1.2 to 2.4), STR to mixed grass pollen (OR, 1.7; 95% CI, 1.1 to 2.7), and STR to mugwort/sage (OR, 2.4; 95% CI, 1.4 to 4.1). African-American ethnicity was associated with STR to four outdoor allergens (*ie*, mixed tree pollen [OR, 2.3; 95% CI, 1.3 to 3.9], mixed grass pollen [OR, 2.7; 95% CI, 1.6 to 4.8], mugwort/sage [OR, 3.1; 95% CI, 1.6 to 6.0], and ragweed [OR, 2.1; 95% CI, 1.2 to 3.8]). Among all children, STR to outdoor allergens was strongly associated with the extent of allergen sensitization. As an example, children sensitized to mixed grass pollen had 34.7 times higher odds of having at least four positive skin tests to other allergens than nonsensitized children (95% CI for OR, 15.6 to 77.0).

Conclusions: Our findings suggest that Puerto Rican ethnicity is associated with an increased risk of sensitization to indoor and outdoor allergens among children with asthma, and that allergy skin testing should be performed more often as part of the management of asthma in African-American children and in Puerto Rican children in the United States.

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Key words: African American; allergen sensitization; childhood asthma; Puerto Rican

Abbreviations: CI = confidence interval; OR = odds ratio; STR = skin test reactivity

In the United States, childhood asthma is a major public health problem among Hispanics in general, and among individuals of Puerto Rican descent

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in particular.^{1,2} Sensitization to aeroallergens is common among asthmatic children,³ and increased asthma severity has been associated with skin test reactivity (STR) to animal dander and STR to multiple allergens.^{4,5} Although cockroach sensitization is known to be common among allergic Puerto Rican children,⁶ there are no available data on the relation between Puerto Rican ethnicity and allergen sensitization among asthmatic children in the United States.

Sensitization to indoor allergens such as cockroach and house dust mite has been associated with increased STR to other allergens,³ but the relation between STR to outdoor allergens and the extent of allergen sensitization among asthmatic children is not completely understood.

In this report, we examine the relationship between ethnicity and STR to aeroallergens among 791 children with mild-to-severe asthma who received

their medical care in the city of Hartford, CT. In addition, we assess whether STR to outdoor allergens is related to an increased number of positive skin tests to allergens among these children.

MATERIALS AND METHODS

The children participating in this study were recruited between June 1, 1998, and October 1, 2002. All children were enrolled in an asthma care program (*ie*, Easy Breathing) and had been referred for allergy skin testing. The Easy Breathing program has been described previously.⁷ In brief, 15,912 children were screened for asthma by their primary care provider during this period. This included 9,391 children who resided in Hartford and 6,521 who resided in communities surrounding Hartford. A diagnosis of asthma was made in 4,031 of the 9,391 children (42.9%) residing in Hartford and in 1,296 of the 6,521 children (19.9%) residing in the communities surrounding Hartford. Of the 4,031 children with asthma residing in Hartford, 2,875 (71.3%) were 4 to 18 years of age. Of the 1,296 children with asthma residing in communities surrounding Hartford, 1,031 (79.6%) were 4 to 18 years of age. Of the 3,906 children with asthma who were enrolled in Easy Breathing and who were 4 to 18 years of age, 791 (20.3%) were referred for allergy skin testing as part of their evaluation and management, and were included in the current study.

Asthma was diagnosed in all children by a physician, and those children had experienced symptoms of asthma (*ie*, cough, wheezing, or shortness of breath) on at least one occasion in the previous 12 months.⁸ The parents and guardians of the children completed a brief questionnaire about demographics, symptoms and triggers of asthma, family history, characteristics of the home environment, exposure to pests (*eg*, cockroaches) in the home, and cigarette smoking. Asthma severity was determined using a scripted set of questions following the guidelines of the National Asthma Education and Prevention Program.^{6,9} Informed consent was obtained from the parents of participating children. The study was approved by the Institutional Review Board of the University of Connecticut Health Center.

Allergy skin testing was performed (Multi Test device; Lincoln Diagnostics; Decatur, IL) with allergen extracts in a 50% glycerin solution. In addition to histamine and saline solution control tests, the following antigens were applied to the skin of the forearm: cockroach (*Blattella germanica*); house dust mite (*Dermatophagoides pteronyssinus*); cat dander; dog dander; mold mix; mixed tree pollen; mixed grass pollen; ragweed; weed mix; and mugwort/sage (Alk-Abello; Round Rock, TX). The result of a test was considered to be positive if the maximum diameter of the wheal was at least 3 mm after subtraction of the measurement of the wheal of the negative control. After a review of its distribution, the number of positive skin test reactions to allergens was categorized as 0, 1 to 3, or at least 4.

The ethnicity of participating children was classified according to parental report, as follows: white; Puerto Rican; African American; and others (including non-Puerto Rican Hispanics [*ie*, < 5% of Hispanics in the study] and Asians). The area of residency of the children in the study was categorized as urban if the child lived in the city of Hartford (325 children) or in a census tract in which the majority of children were covered by Medicaid insurance (*ie*, parts of East Hartford and Waterbury; 29 children), and suburban otherwise.¹⁰ In addition, the following variables were considered for inclusion in the multivariate analysis: type of health insurance (*eg*, Medicaid vs private, self-pay, or uninsured); asthma severity (mild intermittent, mild persistent, moderate persistent, and severe persistent)⁹; maternal history of asthma or

allergies; paternal history of asthma or allergies; eczema in the child; exposure to cockroaches more than twice a week; exposure to rodents more than twice a week; exposure to a pet cat more than twice a week; exposure to a pet dog more than twice a week; and exposure to a gas stove more than twice a week.

Bivariate relationships between the predictor and outcome variables were analyzed with χ^2 tests for pairs of categorical variables or with two-tailed *t* tests for a categorical and a continuous variable. Stepwise logistic regression was used to develop the multivariate models of the relation between ethnicity and STR to each of the 10 allergens tested. As part of the process of developing the multivariate models, we examined collinearity among the independent variables, assessed confounding, and examined interactions. The goodness-of-fit of the final models was tested using the Hosmer-Lemeshow statistic.¹¹ In the final models, we included variables that were significant at $p < 0.05$ or that satisfied a change in the estimate criterion ($\geq 10\%$) in the odds ratio (OR). For the multivariate analysis of the relation between the predictor variables and the number of positive skin tests to allergens, we used multinomial logistic regression.¹¹ This model provides, for a given risk factor, the ratio of the odds of having one to three positive skin test reactions vs none, and the ratio of the odds of having at least four positive skin test reactions vs none. All of the statistical analyses were performed with a statistical software package (SAS; SAS Institute; Cary, NC).

RESULTS

The characteristics of the study participants are summarized in Table 1. The age range of study participants was 4 to 18 years (mean [$\pm$ SD] age, 9.0 ± 3.5 years). In general, children with asthma who were included in the study (*ie*, those referred for allergy skin testing) were similar to other children with asthma who were enrolled in Easy Breathing, with a few exceptions. Regardless of their area of residency, children included in the study had more severe asthma than those not included. Among children living in Hartford, there was no significant difference in parental history of exposure to pets, cockroaches, rodents, or environmental tobacco smoke between children included in the study and those not included. Among children living in the communities surrounding Hartford, there was no significant difference in parental history of exposure to environmental tobacco smoke, cockroaches, rodents, or dogs between children included in the study and those not included. In these children, those included in the study had been exposed to a cat in the household less often than those not included.

Of the 791 children included in the study, 346 (43.7%) were white, 312 (39.5%) were Puerto Rican, 113 (14.3%) were African American, and 20 (2.5%) belonged to other ethnic groups. When compared with white children, Puerto Rican and African-American children were more likely to live in an urban area, to be insured by Medicaid, to have severe persistent asthma, to have eczema, and to be exposed frequently to cockroaches and rodents in their homes.

Table 1—Characteristics of Study Participants*

Variable	White (n = 346)	Puerto Rican (n = 312)	African American (n = 113)	Asians and Others (n = 20)	Total (n = 791)
Sex					
Male	194 (56.1)	154 (49.4)	56 (49.6)	12 (60.0)	416 (52.6)
Female	152 (43.9)	158 (50.6)	57 (50.4)	8 (40.0)	375 (47.4)
Area of residence					
Urban	32 (9.2)	240 (76.9)	73 (64.6)	6 (30.0)	351 (44.4)
Suburban	314 (90.8)	72 (23.1)	40 (35.4)	14 (70.0)	440 (55.6)
Type of health insurance					
Medicaid	95 (27.5)	267 (85.6)	83 (73.5)	15 (75.0)	460 (58.2)
Non-Medicaid	251 (72.5)	45 (14.4)	30 (26.5)	5 (25.0)	331 (41.8)
Asthma severity†					
Mild intermittent	53 (15.5)	49 (15.8)	18 (16.7)	2 (10.0)	122 (15.6)
Mild persistent	125 (36.4)	94 (30.2)	26 (24.1)	10 (50.0)	255 (32.6)
Moderate persistent	144 (42.0)	130 (41.8)	47 (43.5)	7 (35.0)	328 (41.9)
Severe persistent	21 (6.1)	38 (12.2)	17 (15.7)	1 (5.0)	77 (9.9)
Maternal history of asthma or allergies†	69 (20.3)	122 (39.4)	25 (23.4)	6 (30.0)	222 (28.6)
Paternal history of asthma or allergies†	50 (14.7)	53 (17.1)	13 (12.2)	3 (15.0)	119 (15.3)
Eczema†	6 (1.7)	30 (9.6)	9 (8.1)	2 (10.0)	47 (6.0)
Exposure to cockroaches more than two times per week‡	4 (1.2)	67 (22.2)	15 (14.0)	5 (25.0)	91 (11.9)
Exposure to rodents more than two times per week‡	1 (0.3)	27 (8.9)	6 (5.6)	0 (0.0)	34 (4.4)
Exposure to a gas stove more than two times per week‡	10 (3.0)	94 (31.1)	17 (15.9)	6 (30.0)	127 (16.6)
Exposure to a pet cat more than two times per week‡	112 (33.2)	29 (9.6)	12 (11.2)	4 (20.0)	157 (20.5)
Exposure to a pet dog more than two times per week‡	138 (41.0)	68 (22.6)	15 (14.0)	5 (25.0)	226 (29.5)
Skin test reactivity to					
House dust mite	98 (28.3)	140 (44.9)	34 (30.1)	7 (35.0)	279 (35.3)
Cockroach	18 (5.2)	92 (29.5)	21 (18.6)	2 (10.0)	133 (16.8)
Cat dander	117 (33.8)	105 (33.7)	33 (29.2)	6 (30.0)	261 (33.0)
Dog dander	59 (17.1)	33 (10.6)	12 (10.6)	0 (0.0)	104 (13.1)
Mixed tree pollen	54 (15.6)	55 (17.6)	33 (29.2)	5 (25.0)	147 (18.6)
Mixed grass pollen	37 (10.7)	55 (17.6)	28 (24.8)	4 (20.0)	124 (15.7)
Mold	32 (9.2)	29 (9.3)	18 (15.9)	3 (15.0)	82 (10.4)
Ragweed	42 (12.1)	57 (18.3)	23 (20.4)	2 (10.0)	124 (15.7)
Weed mix	17 (4.9)	35 (11.2)	9 (8.0)	1 (5.0)	62 (7.8)
Mugwort/sage	22 (6.4)	42 (13.5)	19 (16.8)	2 (10.0)	85 (10.7)

*Values given as No. (%).

†Missing information on parental history of asthma/allergies, asthma severity, and eczema in 14, 9, and 3 subjects, respectively.

‡Missing information on exposure to cockroaches/rodents/cats/dogs and exposure to a gas stove in 26 and 27 subjects, respectively.

The results of the bivariate and multivariate analyses of the relation between the variables of interest and sensitization to four of the indoor allergens tested (*ie*, cockroach, dust mite, cat, and dog) are summarized in Table 2. In the multivariate analysis, asthma severity was associated with increased odds of sensitization to three allergens (*ie*, cockroach, cat, and dog) and eczema was associated with sensitization to four allergens (*ie*, cockroach, dust mite, cat,

and dog). In this analysis, urban residency was associated with increased odds of sensitization to cockroach, Puerto Rican ethnicity was associated with increased odds of sensitization to cockroach and dust mite, African-American ethnicity and Puerto Rican ethnicity were associated with decreased odds of sensitization to dog, and frequent exposure to cockroaches in the home was associated with increased odds of sensitization to cockroach, dust mite,

Table 2—Predictors of STR to Indoor Allergens*

Variable (Referent)	Cockroach		Dust Mite		Cat		Dog	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Ethnicity (white)								
Puerto Rican	7.6 (4.5–12.9)	3.3 (1.7–6.4)	2.1 (1.5–2.9)	1.7 (1.2–2.4)	1.0 (0.7–1.4)		0.6 (0.4–0.9)	0.5 (0.3–0.8)
African American	4.1 (2.1–8.1)	1.9 (0.9–4.2)	1.1 (0.7–1.8)	0.9 (0.5–1.5)	0.8 (0.5–1.3)		0.6 (0.3–1.1)	0.5 (0.2–1.0)†
Asians and others	2.0 (0.4–9.4)	1.1 (0.2–5.5)	1.4 (0.5–3.6)	1.0 (0.4–2.9)	0.8 (0.3–2.2)		†	†
Eczema (no)								
Yes	3.1 (1.6–5.7)	2.2 (1.1–4.4)	2.9 (1.6–5.3)	2.4 (1.3–4.6)	1.8 (1.0–3.3)	2.1 (1.1–4.0)	2.1 (1.0–4.3)	2.8 (1.3–6.0)
Area of residence (suburban)								
Urban	4.7 (3.1–7.1)	2.1 (1.2–3.5)	1.7 (1.3–2.3)		0.8 (0.6–1.1)		0.7 (0.5–1.1)	
Health insurance (non-Medicaid)								
Medicaid	3.9 (2.5–6.3)		1.9 (1.4–2.5)		1.0 (0.8–1.4)		0.7 (0.5–1.1)	
Mother with asthma/allergies (no)								
Yes	2.3 (1.6–3.4)		1.3 (0.9–1.7)		1.5 (1.1–2.1)		1.5 (0.7–1.8)	
Asthma severity (mild intermittent)								
Mild persistent	2.0 (0.9–4.6)	2.4 (1.0–5.7)	1.0 (0.6–1.6)		1.5 (0.9–2.5)	1.5 (0.9–2.5)	1.2 (0.6–2.8)	1.2 (0.5–2.8)
Moderate persistent	3.5 (1.6–7.6)	3.9 (1.7–8.9)	1.3 (0.8–2.0)		2.2 (1.3–3.5)	2.0 (1.2–3.3)	2.4 (1.2–5.1)	2.4 (1.2–5.1)
Severe persistent	8.1 (3.5–19.1)	7.5 (3.0–18.8)	2.0 (1.1–3.7)		3.8 (2.0–7.1)	3.3 (1.7–6.2)	4.1 (1.8–9.7)	4.9 (2.1–11.8)
Exposed to cockroach more than twice a week (no)								
Yes	5.8 (3.6–9.3)	2.6 (1.6–4.4)	3.0 (1.9–4.7)	2.2 (1.4–3.6)	1.7 (1.1–2.7)	1.9 (1.2–3.2)	0.7 (0.3–1.4)	
Exposure to gas stove more than twice a week (no)								
Yes	3.0 (1.9–4.6)		1.6 (1.1–2.3)		0.6 (0.4–1.0)†	0.5 (0.3–0.7)	0.5 (0.3–1.0)†	

*Values given as OR (95% CI). All of the multivariate models are adjusted for sex and age, in addition to the variables listed in each column.

†p < 0.05.

‡Unable to estimate due to the small number of children in this subgroup.

and cat. Although African-American ethnicity was associated with STR to mold on the bivariate analysis (OR, 1.9; 95% confidence interval [CI], 1.0 to 3.5), we found no significant predictors of STR to mold on multivariate analysis.

Table 3 summarizes the results of the bivariate and multivariate analyses of the relation between the variables of interest and four of the outdoor allergens tested (*ie*, mixed tree pollen, mixed grass pollen, ragweed, and mugwort/sage). In the multivariate analysis, Puerto Rican ethnicity was associated with increased odds of sensitization to mixed grass pollen, mugwort/sage, and weed mix (OR, 2.2; 95% CI, 1.2 to 4.1), and African-American ethnicity was associated with increased odds of sensitization to four outdoor allergens (*ie*, mixed tree pollen, mixed grass pollen, ragweed, and mugwort/sage). In this analysis, asthma severity was associated with increased odds of sensitization to mixed tree pollen and ragweed.

To further examine the observed association between frequent exposure to cockroaches and sensitization to allergens other than cockroach (*ie*, dust mite and cat), we repeated the analysis shown in Table 2 after inclusion of STR to cockroach in the multivariate models. In this multivariate analysis, frequent exposure to cockroaches was still significantly associated with STR to cat (OR, 1.7; 95% CI, 1.0 to 2.9; $p = 0.03$), and STR to dust mite (OR, 1.8; 95% CI, 1.1 to 3.0).

We also were interested in examining the relations among ethnicity, sensitization to specific allergens, and the extent of allergen sensitization (*ie*, the number of positive skin tests) among participating children. In an unadjusted analysis, Puerto Rican ethnicity (OR for four or more vs no positive skin test reactions, 2.3; 95% CI, 1.4 to 3.7) and African-American ethnicity (OR for four or more vs no positive skin test reactions, 2.2; 95% CI, 1.2 to 4.1) were associated with the number of positive skin test reactions to allergens. However, this association became nonstatistically significant after adjusting for asthma severity and other variables. Table 4 summarizes the results of the multivariate analysis of the relation between sensitization to three of the allergens tested (*ie*, cockroach, mixed tree pollen, and mixed grass pollen) and the number of positive skin tests to allergens not included as predictors in each model. A similar analysis was conducted for the relation between STR to each of the remaining seven allergens and the number of positive skin tests to allergens. Sensitization to each of the allergens was significantly associated with the number of positive skin tests, except for STR to weed mix. In particular, STR to dust mite (OR for four or more vs no positive skin test reactions, 9.9; 95% CI, 5.8 to 17.0), STR to mugwort/sage (OR for four or more vs no positive

Table 3—Predictors of STR to Outdoor Allergens*

Variable (Referent)	Mixed Tree Pollen		Mixed Grass Pollen		Ragweed		Mugwort/Sage	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Ethnicity (white)								
Puerto Rican	1.1 (0.8–1.7)	1.1 (0.7–1.7)	1.8 (1.1–2.8)	1.7 (1.1–2.7)	1.6 (1.0–2.5)	1.5 (1.0–2.4)	2.3 (1.3–3.9)	2.4 (1.4–4.1)
African American	2.2 (1.4–3.7)	2.3 (1.3–3.9)	2.7 (1.6–4.7)	2.7 (1.6–4.8)	1.8 (1.1–3.2)	2.1 (1.2–3.8)	3.0 (1.5–5.7)	3.1 (1.6–6.0)
Asians and others	1.8 (0.6–5.1)	1.9 (0.6–5.5)	2.1 (0.7–6.6)	2.2 (0.7–7.1)	0.8 (0.2–3.6)	0.8 (0.2–3.7)	1.6 (0.4–7.5)	1.6 (0.3–7.4)
Eczema (no)								
Yes	1.7 (0.9–3.4)		1.5 (0.7–3.1)		1.7 (0.8–3.4)		2.1 (1.0–4.5)	
Health insurance (non-Medicaid)								
Medicaid	1.2 (0.8–1.7)		1.8 (1.2–2.7)		1.5 (1.0–2.2)		1.6 (1.0–2.6)	
Area of residence (suburban)								
Urban	1.1 (0.8–1.6)		1.3 (0.9–1.8)		1.5 (1.0–2.2)†		1.8 (1.2–2.9)	
Asthma severity (mild intermittent)								
Mild persistent	1.1 (0.6–2.0)	1.1 (0.6–2.1)	1.5 (0.8–2.9)		1.4 (0.7–2.8)	1.5 (0.7–3.0)	1.1 (0.5–2.3)	
Moderate persistent	2.2 (1.2–3.9)	2.2 (1.2–4.0)	1.7 (0.9–3.2)		1.7 (0.9–3.2)	1.7 (0.9–3.3)	1.2 (0.6–2.5)	
Severe persistent	2.9 (1.4–6.0)	2.7 (1.3–5.7)	2.4 (1.1–5.2)		2.7 (1.3–6.0)	2.4 (1.1–5.3)	2.2 (1.2–5.2)	

*Values given as OR (95% CI). All models included sex and age, in addition to the variables listed in each column.

† $p < 0.05$.

Table 4—Predictors of Number of Positive Skin Test Reactions to Aeroallergens on Multivariate Analysis*

Variable (Referent)	Model 1		Model 2		Model 3	
	1-3	At least 4	1-3	At least 4	1-3	At least 4
Asthma severity (mild, intermittent)						
Mild persistent	1.6 (1.0-2.6)†	1.0 (0.5-2.3)	1.9 (1.2-3.1)	1.1 (0.5-2.6)	1.9 (1.2-3.0)	0.7 (0.3-1.7)
Moderate persistent	1.6 (1.0-2.6)†	1.9 (1.0-3.9)	1.6 (1.0-2.6)	1.7 (0.8-3.6)	2.1 (1.3-3.3)	1.9 (0.9-4.0)
Severe persistent	2.5 (1.2-5.1)	4.1 (1.6-10.4)	3.5 (1.6-7.4)	4.2 (1.5-11.6)	4.0 (1.9-8.5)	5.9 (2.2-16.2)
Exposure to cockroaches > 2 times per week (no)						
Yes	1.8 (1.0-3.2)	1.4 (0.6-3.0)	2.9 (1.6-5.5)	3.1 (1.4-6.9)	2.7 (1.5-5.1)	2.7 (1.2-6.0)
STR to cockroach (no)						
Yes	4.0 (2.2-7.4)	6.6 (3.3-13.4)				
STR to mixed tree pollen (no)						
Yes			6.1 (3.1-12.2)	23.8 (11.2-50.4)		
STR to mixed grass pollen (no)						
Yes					4.2 (2.0-8.8)	34.7 (15.6-77.0)

*Values given as OR (95% CI). Multivariate models also adjusted for age and sex; STR to cockroach not included in the outcome for model 1, STR to dust mite not included in the outcome for model 2, and STR to mixed grasses not included in the outcome for model 3.

†p < 0.05.

skin test reactions, 50.6; 95% CI, 17.3 to 147.9), and STR to ragweed (OR for four or more vs no positive skin test reactions, 32.4; 95% CI, 14.4 to 72.9) were each associated with an increasing number of positive skin test reactions. In all of the multivariate models, asthma severity was associated significantly with an increasing number of positive skin test reactions. In these models, frequent exposure to cockroaches was significantly associated with the number of positive skin test reactions, except when adjusting for sensitization to cockroach (model 1 in Table 4).

DISCUSSION

Sensitization to dust mite and sensitization to cockroach are common among Mexican-American children with asthma living in the southwest,¹² and Mexican-American ethnicity has been associated with an increased degree of allergic sensitization among asthmatic children.¹³ To our knowledge, this is the first study to examine the association between Puerto Rican ethnicity and allergen sensitization among asthmatic children in the United States. We found that Puerto Rican children with asthma were more likely to be sensitized to both indoor and outdoor allergens than were white children with asthma.

Our finding of an association between African-American ethnicity and sensitization to outdoor allergens among children with asthma has not been previously reported. African-American ethnicity has been found to predict sensitization to cockroach in children with asthma.^{13,14} Although there was no significant association between STR to cockroach

and African-American ethnicity in the current study, our statistical power to detect such an association was reduced due to a relatively small number of African-American participants.

Poverty is more common among Puerto Ricans and African Americans than in whites in the United States.^{15,16} Poverty is associated with high levels of cockroach allergen in homes in New England,^{17,18} and cockroach exposure is associated with STR to cockroach among inner-city children.¹⁹ In the current study, the association between Puerto Rican ethnicity and STR to cockroach was independent of frequent cockroach exposure, but we had no information on previous cockroach exposure or housing conditions. Hartford has the highest percentage of public housing of any city of its size in the United States.⁷ Most of the housing stock in Hartford is old (91% was built before 1980) and is poorly maintained (the typical house was painted inside in 1950). Thus, our findings could be due to increased exposure to cockroach allergen among poor children living in deteriorated buildings.²⁰

The observed associations between Puerto Rican and African-American ethnicity and STR to outdoor allergens may be due partly to increased allergen exposure due to ethnic differences in the pattern of outdoor activities and residual confounding by area of residency. However, increased allergen exposure is an unlikely explanation for the observed association between Puerto Rican ethnicity and STR to dust mite, because Puerto Rican ethnicity is associated with relatively low dust mite levels in the homes of asthmatic children in New England.^{17,18} Thus, yet-unidentified genetic and environmental factors are

likely to increase susceptibility to STR to dust mite among Puerto Rican children with asthma.

Previous studies of the relation between STR to individual allergens and the number of positive skin test reactions to allergens among asthmatic children have focused on exposure and sensitization to indoor allergens. Among 969 children with mild-to-moderate asthma, most of whom were white, an increasing number of positive skin test reactions was associated with sensitization to each of five indoor allergens.³ In a study¹⁹ of 500 inner-city children with asthma, sensitization to cockroach was associated with an increasing degree of atopy. Among 791 ethnically diverse children with mild-to-severe asthma, we found that sensitization to each of nine indoor and outdoor allergens was significantly associated with an increasing number of positive skin test reactions to other allergens. In particular, STR to outdoor allergens was strongly associated with the extent of allergen sensitization among participating children.

Allergic rhinitis often coexists with asthma and may complicate the management of asthma in childhood.⁹ Allergic rhinitis is strongly associated with the degree of STR to aeroallergens²¹ and with sensitization to outdoor allergens.²² Thus, our finding of a strong association between sensitization to each of four outdoor allergens (*ie*, mixed tree pollen, mixed grass pollen, ragweed, and mugwort/sage) and an increasing degree of allergic sensitization may be due to a relatively high frequency of referrals for allergy skin testing in participating children with symptoms suggestive of allergic rhinitis. An alternative explanation for our findings is that atopy is a dynamic process in which sensitization to outdoor allergens may occur more commonly among asthmatic individuals already sensitized to other allergens, who may be more likely to be referred for allergy skin testing.

Among pregnant women with asthma and allergic diseases, poverty was associated with STR to an outdoor allergen (ragweed) and an increasing degree of atopy but not with physician-diagnosed hay fever, suggesting that allergic rhinitis may be underdiagnosed in the poor.²³ Thus, the association between Puerto Rican and African-American ethnicity and STR to outdoor allergens that was observed in the current study may have been unrecognized previously due to lack of access to allergy skin testing among poor children with asthma and symptoms suggestive of allergic rhinitis.

Sensitization to house dust,²⁴ STR to rye grass, STR to animal dander,^{4,5} and the number of positive skin test reactions to allergens^{4,5} have been found previously to be associated with asthma severity. Sensitization to cockroach has been shown to be associated with increased asthma morbidity,²⁵ but

not with increased asthma severity.⁵ After adjusting for area of residency, ethnicity, and cockroach exposure, we found that asthma severity was associated with STR to cockroach. These results were not changed after inclusion of the type of health insurance in the multivariate analysis (data not shown). Although residual confounding by poverty and access to medical care may explain our results, asthmatic subjects who are sensitized to cockroach are more likely to be steroid-dependent and to have a longer duration of asthma,²⁶ and it is thus possible that cockroach sensitization is associated with increased asthma severity.

We recognize several limitations in our findings. First, this is a cross-sectional study, and thus we cannot establish whether STR to a particular allergen preceded the development of sensitization to other allergens or *vice versa*. Second, we had no information on household income and thus cannot examine whether the observed association between factors such as frequent cockroach exposure and sensitization to allergens other than cockroach is due to factors associated with poverty. However, our results were not changed after adjustment for a surrogate marker of poverty (type of health insurance) and area of residency, suggesting that the observed association may be mediated by factors other than poverty (*eg*, housing conditions).

In summary, we found an association between Puerto Rican ethnicity and an increased risk of sensitization to indoor and outdoor allergens among children with asthma. In these children, African-American ethnicity was associated with an increased risk of STR to outdoor allergens. Our findings suggest that allergy skin testing should be performed more often as part of the management of asthma in African-American children and in Puerto Rican children in the United States.

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