Dust Mite, Cockroach, Cat, and Dog Allergen Concentrations in Homes of Asthmatic Children in the Northeastern United States: Impact of Socioeconomic Factors and Population Density

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Home exposures to aeroallergens are an important environmental factor in allergic sensitization and in the development and exacerbation of asthma. We assessed variations in home concentrations of dust mite, cockroach, cat, and dog allergens in dust collected in the main living areas of asthmatics' homes by family income, mother's education, dwelling type, population density, household population density, and ethnicity in Connecticut and south-central Massachusetts. Dust samples were collected at the time of home interview in 999 homes as part of an ongoing longitudinal birth cohort study of 1,002 infants and their asthmatic siblings. The analysis employed lower and upper cut points for group 1 dust mite (≥ 2.0 μg/g and ≥ 10 μg/g), cockroach (≥ 1.0 U/g and ≥ 4.0 U/g), cat (≥ 1.0 μg/g and ≥ 8.0 ug/g), and dog (≥ 2.0 μg/g and ≥ 10.0 μg/g) allergens. Subject residences were geocoded to assess population density from the U.S. Census, and multiple logistic regression was used to control for confounding. The portion of homes at the lower cut point for dust mite, cockroach, cat, and dog allergens were 46.9%, 24.9%, 42.2%, and 35.6%, respectively; the upper cut point for each of the allergens was reached in 22.4%, 13.4%, 21.0%, and 22.9% of the homes, respectively. In all, 86.0% of the homes had at least one allergen at the lower cut point, and 58.0% had at least one allergen at the upper cut point. Forty-nine percent of the homes had two or more allergens at the lower cut point, and 19.7% had two or more allergens at the upper cut point. Higher education of the mother, higher household income, living in a single-family home in a less densely populated area with fewer people per room, and being a white household were associated with elevated dust mite, cat, and dog allergens and low cockroach allergen. In contrast, low income, living in a multifamily home in a high population density area with a higher occupancy rate per room, and being a Hispanic or black household were associated with elevated cockroach allergens and low concentrations of dust mite, cat, and dog allergens. Although the presence of an individual allergen is more likely associated with one or more socioeconomic or ethnic factors, most homes typically have multiple allergen burdens in excess of concentrations thought to be associated with sensitization and exacerbation of asthma. Mite and cockroach allergens have distinct and opposite associations with socioeconomic factors and population density. *Key words:* aeroallergens, asthma, cats, cockroaches, dogs, dust mites, indoor air, socioeconomic factors. *Environ Health Perspect* 110:419–425 (2002). [Online 12 March 2002]
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A recent report (*1*) issued by the Centers for Disease Control and Prevention estimated that self-reported asthma in the United States rose 75% from 1980 to 1994 with an estimated 17.3 million asthmatics in 1998 (*2*). Over the past two decades the prevalence and severity of asthma among children has been increasing (*1,3–5*). Asthma has a considerably greater impact on Hispanic and African Americans than on white Americans (*1,6–8*). African-American children have higher asthma prevalence rates (1.1–1.7 times) than whites (*1,4,9,10*), 2–3.5 times the hospital admission rate for asthma as whites (*1,11*), and approximately 2–5 times the asthma mortality rate as for whites (*1,12–16*). Point prevalence asthma rates of 11.2% and cumulative prevalence rates (ever had asthma) of 20.1% have been reported for Puerto Rican children, the highest rates for any ethnic group in the United States (*6,12*). Hospitalization and death rates for Hispanics are 3–4 times those of white Americans (*4,9,11,17,18*).

No single factor is likely to account for the observed increase in the prevalence and severity of asthma, particularly the increases observed in minority populations. These increases are likely due to a combination of factors, including environmental, cultural, and socioeconomic factors; access to medical care; and interactions between environmental exposures and genetic susceptibility. Exposure to aeroallergens has been identified as a major environmental risk factor in the development of asthma in children, as an important determinant of asthma severity in children, and possibly as a key variable in accounting for the observed increase in the prevalence and severity of asthma in children observed over the past two decades (*17,19–28*).

The Connecticut Childhood Asthma Study (CHAS) is a longitudinal cohort study of asthma development and morbidity in a birth cohort of 1,002 infants and their asthmatic siblings. We explored the socioeconomic and population density predictors of home allergen levels in this large, socioeconomically diverse, at-risk population, which was composed of a large proportion of African-American and Hispanic households.

Methods

Cohort. Between September 1996 and December 1998, 33,341 women delivering babies in five Connecticut hospitals and in one hospital in south-central Massachusetts were screened for inclusion in the study. Mothers who had a child at home younger than 11 years of age with a physician diagnosis of asthma were invited into the study. Of the 1,448 families identified as eligible for the study, 1,002 enrolled, 334 declined to participate, and 112 could not participate for technical reasons (moving out of the area, no telephone, etc.). A trained research assistant visited each home and administered an initial questionnaire to each mother to obtain information about home and family characteristics, as well as potential environmental exposures for the index infant and the asthmatic sibling. In this analysis we use information gathered from the initial questionnaire.

Collection and analysis of dust samples. At the initial home interview, a research assistant collected dust samples in the index infant's bed, the asthmatic sibling's bed, and the main living area using a standardized protocol. This analysis used only allergen data measured from dust samples collected in the main living area of each home. Dust samples were collected using a Eureka Mighty Mite II portable vacuum cleaner (The Eureka Company, Bloomington, IL) fitted with a Whatman cellulose extraction thimble (single thickness, 19 × 90 mm). All vacuum-cleaner attachment adapters were cleaned with detergent and rinsed with deionized water and then with ethanol to prevent contamination between samples. Vacuum-cleaner attachments and thimbles were kept in clean, zipper-locking plastic bags until use. After each sampling, the thimble containing the collected sample was sealed and placed in a zipper-locking plastic bag for transport to the laboratory. Using one thimble, dust sampling was conducted for 3 min over the exposed seat cushions, seat back, and arms of a couch or chair in the main living area of each home (the room where the family spent most of its time and the couch/chair most frequently used) and for 2 min over a 1.0-m² area of the floor in the main living area. If the room had smooth flooring with a throw rug, we sampled 0.5 m² on the rug and 0.5 m² on the smooth floor.

We analyzed collected dust samples for levels of house dust mite allergen (Der p 1 and Der f 1), cockroach allergen (Bla g 1), cat allergen (Fel d 1), and dog allergen (Can f 1). The samples were sifted through a 425-μm mesh sieve and weighed. The sifted dust samples were prepared by extracting 100 mg of the fine dust in 2 mL PBS-T (phosphate buffered saline with Tween 20). The mite allergens were assayed by ELISA (enzyme-linked immunosorbent assay) for Der p 1 and Der f 1 (*29,30*). Samples were assayed for Fel d 1, Can f 1, and Bla g 1 using two-site monoclonal antibody-based ELISA (*23,31*). Dust pellets remaining after extraction and any remaining extract were stored at –70°C. Results are reported in micrograms per gram of fine dust for Der p 1, Der f 1, Fel d 1, and Can f 1 and units per gram of dust for Bla g 1. The detection limit for Der p 1 and Der f 1 was 0.1 μg/g, 0.12 μg/g for Fel d 1 and Can f 1, and 0.6 U/g for Bla g 1.

Geographical information system mapping and population density. Each subject's residence was geocoded using enhanced TIGER files obtained from Wessex and the software package ArcView (ESRI, Inc., Redlands, CA). This provided latitude and longitude coordinates for each individual, allowing us to produce a map showing place of residence. Most of the subjects in this study (81%) resided in Connecticut,

with the remaining 19% living in areas of Massachusetts and New York State bordering Connecticut. The success rate of the geocoding among the study population was 97%.

We used geocoded residence information to identify the census tract in which the individual lived by determining whether the point of residence was within the census tract polygon. Population density (persons per square mile) for each census tract was derived from information provided by the 1990 U.S. Census (*32*).

Statistical analysis. Der p 1 and Der f 1 were summed into one variable to focus the analysis on the group 1 dust mite allergen (Der 1). Lower and upper cut points of the distributions for Der 1, Fel d 1, and Can f 1 were selected based on levels identified in the literature as potentially related to sensitization (moderate level) or asthma exacerbation (high level). Lower and upper cut points were ≥ 2.0 μg/g and ≥ 10 μg/g (*33*) for group 1 dust mite; ≥ 1.0 μg/g and ≥ 8.0 μg/g for Fel d 1; and ≥ 2.0 μg/g and ≥ 10.0 μg/g for Can f 1 (*23,34*). Because there are no agreed-upon minimum concentrations for sensitization or exacerbation for cockroach allergen, we chose ≥ 1.0 U/g and ≥ 4.0 U/g as moderate and high concentration cut points for Bla g 1 for our analysis (*27*).

Unadjusted relationships between socioeconomic factors and main living area concentrations above the low and high cut

points were evaluated using odds ratio (OR) estimates along with their 95% confidence intervals (CIs). We used multiple logistic regression to investigate the simultaneous effect of the factors on the upper allergen cut points. Adjusted ORs and their 95% CIs were computed from the logistic regression coefficients and the corresponding standard errors. Statistical analysis was carried out using SAS version 6.12 (*35*).

Results

Population characteristics. Dust sampling was conducted in 999 homes, 81% of which were located within Connecticut and 19% in the bordering states of Massachusetts and New York (Table 1). Minorities composed 41% of the population; Hispanics (95% of whom were Puerto Rican), the largest minority group, composed 27% of the population) and African Americans composed 14%. A large percentage of the population had an annual household income < $20,000 (30%), and 41% had ≤ 12 years of education. Approximately one-fifth of the households were multiple-family structures housing four or more families. A wide range of population densities (59 to > 31,000 persons/mile²) was estimated with approximately one-third of the population living in low-density areas (< 1,150 people/mile²) and one-third living in high-density areas (≥ 5,400 people/mile²) such as the cities of New Haven, Bridgeport, and Hartford, Connecticut. Approximately one-half of the

Table 1. Characteristics of a cohort of 999 women with one or more asthmatic children, southern New England, United States, 1996–1998.

Variable	No.	Percent
Residence		
Inside Connecticut	805	81
Outside Connecticut	194	19
Maternal education		
< High school	163	16
High school	263	26
Some college	268	27
> College	308	31
Annual income		
< $20,000	276	30
$20,000–$50,000	212	23
> $50,000	443	47
Race		
White	547	55
Black	137	14
Hispanic	265	27
Other	44	4
Dwelling type		
Single to three families	788	79
Four or more families	214	21
Population density (persons/mile²)[a]		
< 1,150	321	33
1,150 to < 5,400	324	34
> 5,400	320	33
Household density (people/room)		
< 1	555	56
> 1	442	44

[a]Calculated by locating each address within a census tract and assigning population densities for that tract from the 1990 U.S. Census data (*32*).

Table 2. Distribution of allergen levels in dust in the main living area of homes of 999 women with one or more asthmatic children, southern New England, United States 1996–1998.

Allergens	No.	Percent
Group 1 mite allergen (μg/g)[a]		
< 0.20	197	19.8
0.20 to < 0.5	119	12.0
0.50 to < 2.0	212	21.3
2.0 to < 10.0	243	24.5
≥ 10	222	22.4
Fel d 1 (μg/g), cat		
< 0.12	159	16.0
0.12 to < 0.5	261	26.3
0.50 to < 1.0	154	15.5
1.0 to < 8.0	210	21.2
≥ 8.0	209	21.0
Can f 1 (μg/g), dog		
< 0.12	176	17.7
0.12 to < 0.5	214	21.6
0.5 to < 2.0	248	25.0
2.0 to < 10	135	13.6
≥ 10	227	22.9
Bla g 1 (U/g), cockroach		
< 0.6	713	71.9
0.6 to < 1.0	31	3.2
1.0 to < 2.0	63	6.4
2.0 to < 4.0	51	5.1
4.0 to < 8.0	41	4.1
≥ 8.0	92	9.3

[a]Group 1 mite allergen = Der p 1 + Der f 1.

population lived in a home where the household density (number of occupants per number of rooms in the home) was < 1.

Allergen concentrations. Table 2 presents the concentration distributions of allergens. Group 1 dust mite allergen concentrations ≥ 2.0 μg/g (lower cut point) were found in the living room dust of 46.9% of the homes, and concentrations ≥ 10.0 μg/g (upper cut point) were recorded in 22.4% of the homes. Cat allergen levels at the lower cut point (≥ 1 μg/g) were found in 42.2% of the homes, and 21% had levels at the upper cut point (≥ 8 μg/g). Dog allergen levels at the lower cut point (≥ 2 μg/g) were measured in 36.5% of the homes, and 22.9% of the homes had levels at the upper cut point (≥ 10 μg/g). Cockroach allergen levels ≥ 1.0 U/g (lower cut point) were found in 24.9% of the homes, and 13.4% of the homes had levels ≥ 4.0 U/g (upper cut point). For each allergen, a substantial number of homes had concentrations below the detection limit (e.g., 71.9% of the homes had allergen levels ≤ 0.6 U/g of Bla g 1).

In our sample of 999 homes, 86.0% had at least one allergen at the lower cut point, and 58.0% had at least one allergen at the upper cut point. Homes typically had multiple allergens at the upper and lower cut points. Two or more allergens at the lower cut point were found in 49.0% of the homes, and 19.7% of the homes had two or more allergens at the upper cut point. Figure 1 demonstrates the degree of overlap for homes having group 1 dust mite, cockroach, and cat allergen concentrations at the lower cut point (Figure 1A) and upper cut point (Figure 1B).

Bivariate analysis. Figures 2–5 present the unadjusted ORs with 95% CIs for allergen concentrations at the lower and upper cut points for group 1 dust mite, cockroach, cat, and dog allergens.

The unadjusted ORs for having group 1 dust mite, cat, and dog allergens at the lower or upper concentration cut points increased with higher education level of the mother, increasing level of annual family income, decreasing population density, living in a single-family house, having a household density of < 1, and being a white household (Figures 2–4). In contrast, the unadjusted ORs of having cockroach allergen at the lower or upper concentration cut points was the reverse of that seen for dust mite, cat, and dog allergens (Figure 5). Cockroach allergen-unadjusted ORs increased with decreasing level of mother's education, decreasing level of annual family income, increasing population density, living in a multifamily dwelling, having a household density of ≥ 1, and being a black or Hispanic household.

Multivariate models. Results of the logistic regression analysis are presented in Table 3. Sociodemographic factors and dwelling type were independently associated with moderate levels (≥ 2.0 μg/g) of group 1 dust mite allergen. In particular, being less well educated, poor, black or Hispanic, and living in a multiple-family home were independently associated with a reduced likelihood of having dust mite levels ≥ 2 μg/g. Only population density was found to be independently associated with having dust mite levels ≥ 10.0 μg/g at the 0.05 significance level, with living in a less populated area associated with an increased likelihood.

In contrast, being poorer, black or Hispanic, living in a more densely populated area, and having a higher household density independently increased the likelihood of having levels of Bla g 1 above both cut points. In addition, living in a multifamily dwelling increased the likelihood of having levels of Bla g 1 ≥ 4.0 U/g.

Being black or Hispanic provided a strong reduced likelihood of having both cat and dog allergen levels above moderate and high cut points. In addition, living in a multiple-family dwelling was associated with a reduced likelihood of having dog allergen levels ≥ 2.0 and ≥ 10.0 μg/g.

Discussion

Several studies conducted in the United States (20,26,27,34,36,37) have measured levels of dust mite, cockroach, cat, and dog allergens in household dust. These studies have typically been conducted in urban areas and on study populations that tend to be restricted in their ethnic and socioeconomic diversity. The National Cooperative Inner-City Asthma Study (20) and the Harvard Asthma Study (26) are two large studies conducted in the United States that have added a substantial amount of information on the nature of allergens in home dust. Both found that low family income, low maternal education, multifamily dwellings, and ethnicity (black or Hispanic versus white) are associated with high cockroach and low dust mite, cat, and dog allergen concentrations in house dust. These studies were typically conducted within large metropolitan areas such as New York City, Chicago, and Boston (densely populated), where the study populations primarily lived in multifamily dwellings and were of limited income and ethnic diversity.

The population (*n* = 476) for the National Cooperative Inner-City Asthma Study (NCICAS), drawn from large metropolitan areas, was primarily black (73.5%), had low annual income (61.2% < $15,000/year), lived in multifamily dwellings, had high cockroach allergen dust exposures (median of 8.2 U/g) and low dust-mite and cat allergen dust exposures (9.7% ≥ 2 μg/g and 12.6% ≥ 2 μg/g, respectively). Extensive data on home allergen levels were reported for the Harvard Asthma Study (HAS), conducted in the Boston metropolitan area as part of a longitudinal birth cohort study of 499 children. This population, in contrast to the NCICAS study, was largely white (74%), better educated (78% with ≥ a college education), had a higher income (70% ≥ $50,000/year), and lived in a heavily populated urban area in primarily multifamily dwellings. In the HAS study, 24% of the homes had either dust mite concentrations from 2 to < 10 μg/g and 42% ≥ 10 μg/g; 13% had cockroach levels ≥ 2 U/g; 41% had cat allergen levels between 1 and < 8 μg/g and 26% ≥ 8 μg/g; and 20% had dog allergen concentrations ≥ 8 μg/g.

Our study was more heterogeneous than either the NCICAS or HAS studies with a greater range in attained education, ethnic diversity, housing type, and population
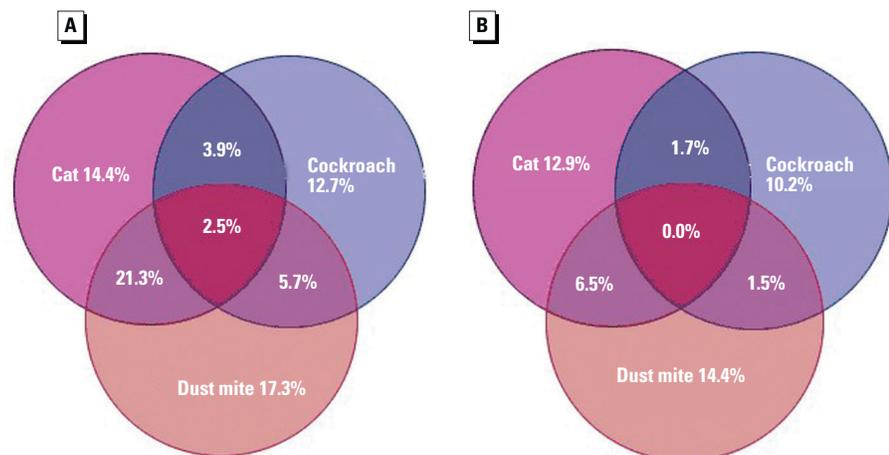
Figure 1. Allergen distribution of percentage of homes with overlapping group 1 dust mite, cockroach, and cat allergen dust concentrations at (*A*) the lower cut points (group 1 dust mite ≥ 2.0 μg/g, cockroach ≥ 1.0 U/g, and cat ≥ 1.0 μg/g; 22.1% of homes are below the lower cut point) and (*B*) the upper cut points (group 1 dust mite ≥ 10.0 μg/g, cockroach ≥ 4.0 U/g, and cat ≥ 8.0 μg/g; 52.8% of homes are below the upper cut point). From a cohort of 999 women with one or more asthmatic children, southern New England, United States, 1996–1998.

density. Despite differences in the populations studied, measured allergen levels in our study were remarkably similar to the HAS study. The larger population followed in our study ($n = 999$) versus the HAS study ($n = 499$) provides more power in examining the association between allergen levels, housing characteristics, and socioeconomic variables.

Our measured allergen levels were markedly different from those of the NCICAS study, which had considerably higher levels of cockroach allergen and much lower levels of dust
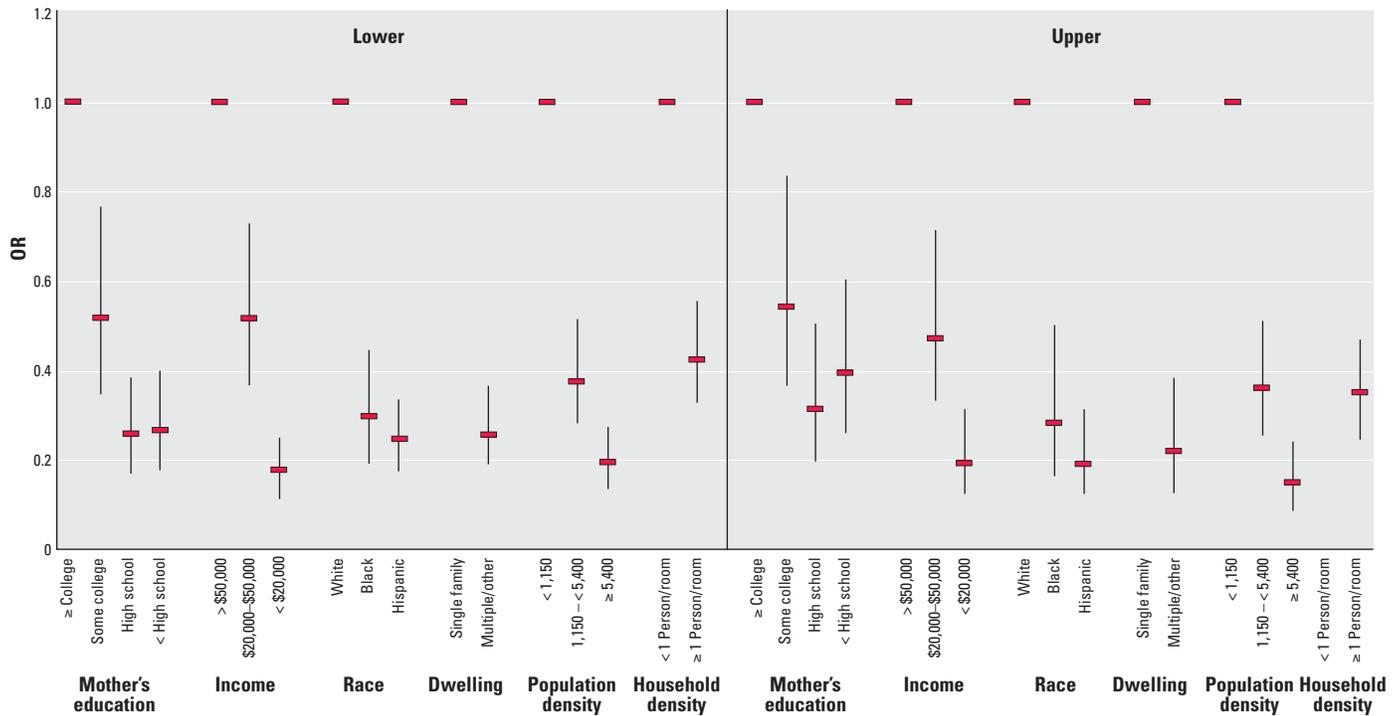

Figure 2. Unadjusted ORs with 95% CIs for lower (≥ 2.0 µg/g) and upper (≥ 10.0 µg/g) cut point concentrations for group 1 dust mite allergen (Der p 1 + Der f 1) by socioeconomic risk factors, population density (persons/mile^2), and household density (persons/room). Allergens were measured in dust collected in the main living areas of 999 homes of a cohort of 999 women with one or more asthmatic children, southern New England, United States, 1996–1998.

Figure 3. Unadjusted ORs with 95% CIs for lower (≥ 1.0 µg/g) and upper (≥ 8.0 µg/g) cut point concentrations for cat allergen (Fel d 1) by socioeconomic risk factors, population density (persons/mile^2), and household density (persons/room). Allergens were measured in dust collected in the main living areas of 999 homes of a cohort of 999 women with one or more asthmatic children, southern New England, United States, 1996–1998.
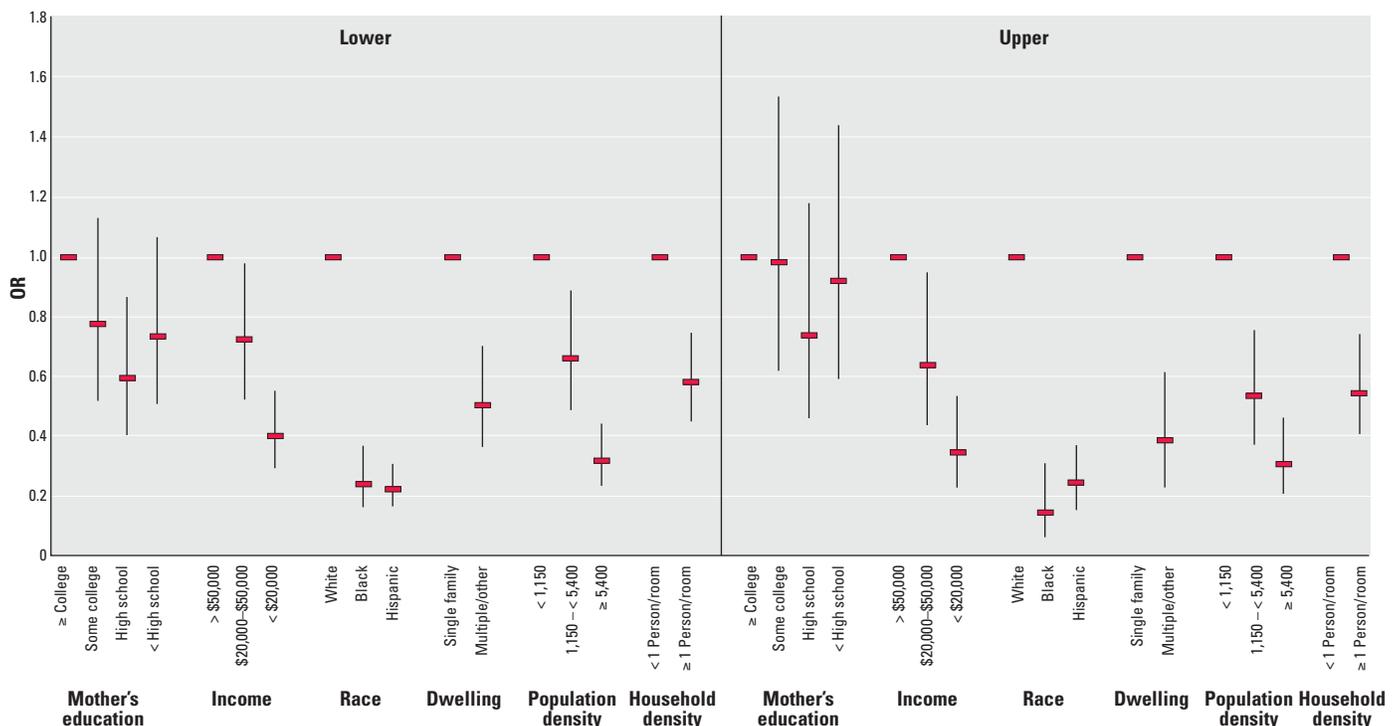
mite and cat allergen. These concentration differences are likely to be related to housing differences. The NCICAS was conducted exclusively in high-poverty, inner-city

locations, where housing is more likely to be substandard, and in multifamily dwellings, and where the ownership of dogs and cats is low. We had a more varied housing stock,

with measured dust mite and cat allergen levels higher and cockroach levels much lower.

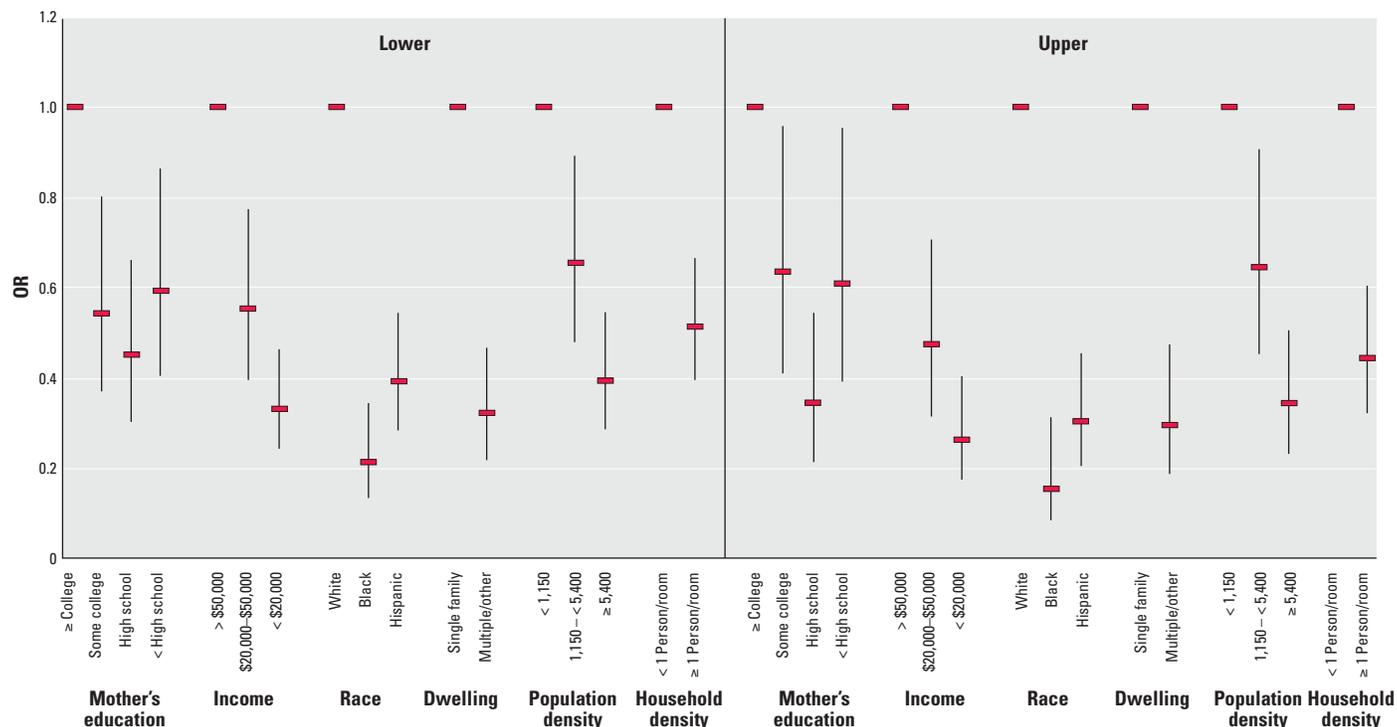Our results highlight the differences in type and level of allergen measured in homes

Figure 4. Unadjusted ORs with 95% CIs for lower (≥ 2.0 µg/g) and upper (≥ 10.0 µg/g) cut point concentrations for dog allergen (Can f 1) by socioeconomic risk factors, population density (persons/mile[2]), and household density (persons/room). Allergens were measured in dust collected in the main living areas of 999 homes of a cohort of 999 women with one or more asthmatic children, southern New England, United States, 1996–1998.

Figure 5. Unadjusted ORs with 95% CIs for lower (≥ 1.0 U/g) and upper (≥ 4.0 U/g) cut point concentrations for cockroach allergen (Bla g 1) by socioeconomic risk factors, population density (persons/mile[2]), and household density (persons/room). Allergens were measured in dust collected in the main living areas of 999 homes of a cohort of 999 women with one or more asthmatic children, southern New England, United States, 1996–1998.
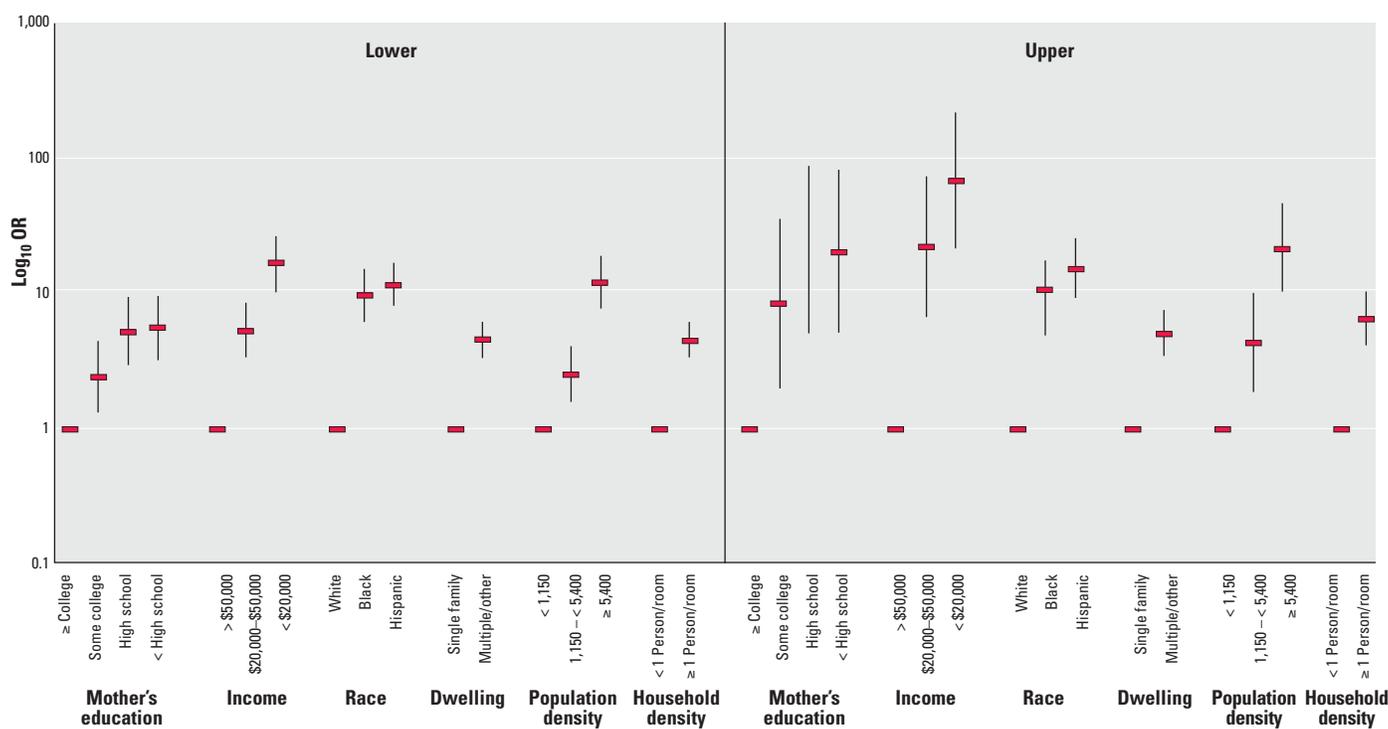
by socioeconomic variables. Using two cut points, a lower one associated with allergen sensitization and an upper one associated with the exacerbation of asthma in sensitized individuals, we assessed how socioeconomic and ethnic variables predicted risk for elevated allergen levels in homes. Indicators of low socioeconomic and minority status were associated with a high likelihood of cockroach allergen in home dust at concentrations in excess of both the lower and upper concentration cut off points and a low likelihood of having group 1 dust mite, cat, and dog allergen levels in excess of both lower and upper cut points. In contrast, indicators of high socioeconomic status were strongly associated with having a high likelihood of elevated levels of group 1 dust mite, cat, and dog allergens and a low risk of elevated concentrations of cockroach allergen.

Because higher cockroach levels are likely in substandard, multifamily dwellings located in high-density areas and occupied by low-income, minority families with a low attained education level, it is difficult to disentangle the role of individual socioeconomic factors in producing high cockroach levels. Although our sample included cities where the population density is high (New Haven, Bridgeport, and Hartford, Connecticut, and Springfield, Massachusetts), the population densities were lower than those in large urban centers, which were the focus of the NCICAS

and HAS studies. In our study, the percentage of homes with elevated cockroach levels (≥ 1.0 U/g) increased with the number of families in the multifamily structure from 17.2% for two-family homes to 27.5% for greater than six families.

It is not clear why high socioeconomic status is associated with a high risk of elevated group 1 dust mite concentrations. Higher socioeconomic status may be associated with homes in which conditions for dust mite proliferation in the main living areas are more advantageous. These conditions include such factors as more favorable dust mite nesting sites (i.e., carpeting, upholstered furniture, and fabric draperies), more optimal temperature for mite growth, and high humidity. Higher humidity levels might be associated with reduced air infiltration rates associated with newer, more energy-efficient homes. It has been suggested that low dust mite concentrations associated with poorer multifamily households may be due to higher temperatures and thus lower humidity maintained in these homes during the heating season (38).

Other studies have demonstrated that cat allergen levels vary by socioeconomic status and ethnicity (20,26,34,36), with elevated levels associated with white, single-family homes and high socioeconomic status. In our study, cat allergen in homes varied by ethnicity. However, once this factor was included

in the logistic regression model, the other factors did not achieve statistical significance, suggesting that it may be difficult to separate socioeconomic status and ethnicity in identifying high cat-allergen exposures. It may be that white families more than minorities prefer to keep cats or that minorities are more likely to keep their cats outdoors. Relatively few data are available on home concentrations of dog allergens (23). In our study, dog allergen concentrations, like those for cat allergens, varied by ethnicity but also by housing type. Our results suggest that elevated dog allergen levels are associated with being white and living in single-family homes. Dogs are typically not allowed or are not practical to keep in multifamily homes.

Being of low socioeconomic and minority status does not mean that the allergen burden is only associated with cockroach allergen. Our data suggest that many homes have multiple allergen burdens at levels that are of health interest. Although socioeconomic status may be a useful predictor of identifying the potential for a major allergen in a home, it may be a poor predictor of levels of multiple allergens at concentrations with potential health effects.

This analysis used only allergen concentrations from dust collected in the main living area of the homes and not the bedding of the index infant or asthmatic sibling. The main living room allergen levels for dust

Table 3. Final logistic regression models for allergens at two cut points by socioeconomic factors, dwelling type, and population density for 999 women with one or more asthmatic children, southern New England, U.S. 1996–1998.[a]

Variable	Group 1 mite allergen		Bla g 1		Fel d 1		Can f 1	
	> 2 µg/g	≥ 10 µg/g	> 1.0 U/g	> 4.0 U/g	≥1.0 µg/g	≥ 8.0 µg/g	≥ 2.0 µg/g	≥ 10.0 µg/g
Mother's education								
< High school	0.55**	0.75	1.00	3.80	1.24	1.60	0.86	0.88
	(0.35–0.86)	(0.47–1.20)	(0.46–2.19)	(0.46–31.08)	(0.80–1.93)	(0.97–2.64)	(0.55–1.33)	(0.55–1.41)
High School	0.52**	0.70	0.75	3.72	1.09	1.50	0.78	0.62
	(0.32–0.85)	(0.41–1.19)	(0.34–1.62)	(0.46–29.96)	(0.68–1.76)	(0.86–2.61)	(0.48–1.26)	(0.36–1.07)
Some college	0.80	0.90	0.71	3.43	1.00	1.47	0.70	0.85
	(0.51–1.25)	(0.56–1.44)	(0.33–1.53)	(0.42–27.81)	(0.64–1.55)	(0.88–2.43)	(0.45–1.08)	(0.53–1.37)
> College	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Annual income								
< $20,000	0.40**	0.58*	4.15**	11.86**	1.33	0.92	0.76	0.64
	(0.25–0.65)	(0.31–1.07)	(2.19–7.86)	(3.34–42.05)	(0.81–2.19)	(0.51–1.68)	(0.46–1.25)	(0.35–1.17)
$20,000–$50,000	0.75	0.74	2.45**	7.33**	1.26	0.88	0.93	0.75
	(0.50–1.14)	(0.46–1.21)	(1.31–4.58)	(2.07–25.96)	(0.82–1.93)	(0.54–1.44)	(0.61–1.41)	(0.46–1.22)
> $50,000	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Ethnicity								
Black	0.58**	0.61	3.59**	2.61**	0.22**	0.15**	0.25**	0.18**
	(0.36–0.94)	(0.33–1.13)	(2.08–6.19)	(1.28–5.34)	(0.13–0.36)	(0.07–0.33)	(0.14–0.45)	(0.08–0.41)
Hispanic	0.65*	0.62	2.23**	2.10**	0.21**	0.24**	0.55**	0.41**
	(0.41–1.04)	(0.33–1.14)	(1.30–3.82)	(1.05–4.21)	(0.13–0.34)	(0.13–0.46)	(0.34–0.90)	(0.22–0.75)
White/other	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Dwelling type								
Single family	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Multiple family	0.54**	0.64	1.41	1.72**	1.00	0.88	0.47**	0.52**
	(0.35–0.83)	(0.35–1.19)	(0.93–2.14)	(1.08–2.72)	(0.65–1.54)	(0.50–1.57)	(0.30–0.75)	(0.28–0.97)
Population density[b]	0.87	0.74**	1.35**	1.20**	0.87	1.01	1.07	1.19
	(0.73–1.03)	(0.57–0.96)	(1.15–1.60)	(1.01–1.43)	(0.73–1.03)	(0.81–1.26)	(0.90–1.26)	(0.97–1.46)
Household density	1.44	0.77	3.55**	3.70**	1.11	0.85	0.84	0.08
	(0.84–2.46)	(0.38–1.53)	(1.88–6.72)	(1.85–7.40)	(0.65–1.90)	(0.44–1.65)	(0.49–1.45)	(0.43–1.60)

Ref, reference values. Values shown are adjusted ORs (CIs).
[a]Lower and upper cut points were selected based on potential for development of sensitization (lower) and asthma excacerbation (upper). [b]Calculated by locating each address within a census and assigning population densities for that tract from the 1990 U.S. Census data (32); the OR refers to increase in population density of 5,000 persons/mile². *0.05 < p < 0.10. **p < 0.05.

mite, cat, dog, and cockroach allergens were typically the highest levels measured in the homes, being higher than or equal to levels in the bedding in 60–94% of the homes. Using the bedding allergen levels did not change the results. Dust samples were not available for kitchens, where cockroach allergens would be expected to be highest; thus cockroach concentrations in the main living area are probably an underestimate of the highest levels in each home, but are probably a good indicator of the presence of cockroach allergen in the home.

Dust samples were collected in our study over a 3-year period and across all seasons. Dust mites thrive in higher relative humidity, and dust mite allergen concentrations in homes may vary by season (*38*). Our sample was recruited and house dust sampling conducted without any seasonal bias for housing type, population density, or socioeconomic status.

Sensitization to indoor allergens and the role of indoor allergens in the exacerbation of asthma in children, in part, is related to the concentration/time profile of the exposure. In this and all previous studies (*20,26*), a point-in-time measurement of indoor allergen concentrations is presented. It is not known how the exposure level may change in time. We are currently revisiting all homes and conducting a second round of sampling, 3 years after our initial visit, to assess how allergen exposures vary over time. It is also not known how allergen levels in the dust relate to actual inhalation exposures. An assumption is made that dust concentrations are at least a proxy for inhalation exposures. This assumption may introduce misclassification in assigning exposures to house occupants.

Lower and upper cut point concentrations were selected for our analysis based on the available literature. These cut points, however, are somewhat arbitrary and need to be interpreted with caution. The lower cut point used in this analysis to represent an increased risk for cockroach sensitization (≥ 1.0 U/g), for example, may be too high. A recent report suggests that sensitization may occur at a concentration < 1.0 U/g (*27*). Using the detection limit (0.6 U/g) as the lower cut point in this analysis did not change the results. As the nature of the relationship among allergen exposure, sensitization, asthma development, and asthma severity is better understood, new cut points that relate to disease onset and severity may emerge.

The size and diversity of the sample and composition of the study population adds substantially to the database on the nature of dust mite, cockroach, cat, and dog allergen levels in homes of asthmatics in the northeastern United States. However, all homes included at least one asthmatic child, and, therefore, the homes may not be representative of the general population. Furthermore, the sample was drawn from one region of the United States. How the allergen levels measured in this study compare to allergen levels in homes of a more statistically representative sample of U.S. homes remains to be seen. The type and nature of indoor allergens may vary considerably by location in the United States and other parts of the world, as may the socioeconomic and ethnic factors that impact them. In addition, this study was limited to a relatively few, although important, allergens. There are, however, other allergens in homes that were not measured, but which may contribute substantially to the home allergen load (e.g., rat, mouse, and bird).

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