Journal of Urban Health: Bulletin of the New York Academy of Medicine, Vol. 91, No. 4
doi:10.1007/s11524-014-9872-9

Associations of Neighborhood Concentrated Poverty, Neighborhood Racial/Ethnic Composition, and Indoor Allergen Exposures: a Cross-Sectional Analysis of Los Angeles Households, 2006–2008

Marlene Camacho-Rivera, Ichiro Kawachi, Gary G Bennett, and S. V. Subramanian

ABSTRACT *Although racial/ethnic, socioeconomic, and neighborhood factors have been linked to asthma, and the association between indoor allergens and asthma is well documented, few studies have examined the relationship between these factors and indoor allergens. We examined the frequency of reported indoor allergens and differences by racial/ethnic, socioeconomic, and neighborhood characteristics among a diverse sample of Los Angeles households. Multilevel logistic regression models were used to analyze the data from 723 households from wave 2 of the Los Angeles Family and Neighborhood Survey. The reported presence of rats, mice, cockroaches, mold, pets, and tobacco smoke were the primary outcomes of interest. Hispanic and Asian households had a nearly threefold increase in the odds of reporting cockroaches compared to non-Hispanic Whites (OR, 2.85; 95 % CI 1.38–5.88 and OR, 2.62; 95 % CI 1.02–6.73, respectively) even after adjusting for socioeconomic factors. Primary caregivers who had obtained a high school degree were significantly less likely to report the presence of mice and cockroaches compared to primary caregivers with less than a high school degree (OR, 0.19; 95 % CI 0.08–0.46 and OR, 0.39; 95 % CI 0.23–0.68, respectively). Primary caregivers with more than a high school degree were also less likely to report the presence of rats, mice, and cockroaches within their households, compared to those with less than a high school degree. Compared to renters, home owners were less likely to report the presence of mice, cockroaches, and mold within their households. At the neighborhood level, households located within neighborhoods of high concentrated poverty (where the average poverty rate is at least 50 %) were more likely to report the presence of mice and cockroaches compared to households in low concentrated poverty neighborhoods (average poverty rate is 10 % or less), after adjusting for individual race/ethnicity and socioeconomic characteristics. Our study found evidence in support of neighborhood-level racial/ethnic and socioeconomic influences on indoor allergen exposure, above and beyond individual factors. Future studies should continue to explore individual and neighborhood-level racial/ethnic and socioeconomic differences in household allergen exposures across diverse contexts.*

KEYWORDS *Neighborhood characteristics, Indoor allergens, Multilevel models, Children, Asthma, Los Angeles*

Camacho-Rivera is with the Department of Population Health, North Shore-Long Island Jewish Health System, Great Neck, NY, USA; Kawachi and Subramanian are with the Department of Social and Behavioral Sciences, Harvard School of Public Health, Boston, MA, USA; Bennett is with the Department of Psychology and Neuroscience, Duke University, Durham, NC, USA.

Correspondence: S. V. Subramanian, Department of Social and Behavioral Sciences, Harvard School of Public Health, Boston, MA, USA. (E-mail: svsubram@hsph.harvard.edu)

INTRODUCTION

In the US, asthma is one of the most prevalent chronic conditions affecting millions of children, resulting in frequent emergency room visits, hospitalizations, and even disability and death.[1,2] However, the burden of asthma is not born evenly; significant disparities exist along racial/ethnic, socioeconomic, and geographic lines.[3–8] Compared with white children, non-Hispanic black children and Puerto Rican children are more likely to have current asthma. Within the US, the higher prevalence rates of asthma and asthma morbidity have been well-documented among children living in low-income neighborhoods within urban cities. These disparities have led to an increase in research focusing on the impact of neighborhood characteristics on childhood asthma.[9–19] An extensive body of research has examined the characteristics and quality of the housing environment.[20–31] Exposure and sensitization to household allergens such as environmental tobacco smoke,[32–34] cockroaches,[35–40] mold,[41–43] dust mites,[40,41,44–46] mice,[37,40,47–50] and pets[40,51,52] have been linked to airway hyperresponsiveness, wheezing, and increased likelihood in developing asthma.[53–58] Among asthmatic children, exposure to allergens have been associated with increased asthma attacks and hospitalizations, as well as increased medication use.[41,46,59,60]

While researchers have found low-income neighborhoods to have a higher prevalence of suboptimal housing conditions, only one study to our knowledge has explicitly examined the link between neighborhood-level characteristics and household allergens.[61] Although several features of neighborhoods have been linked to asthma and the association between indoor allergens and asthma is well documented, factors such as neighborhood poverty and racial/ethnic composition may influence asthma outcomes through the quality of housing conditions, which can impact allergen levels. While research examining disparities in asthma outcomes in Los Angeles have focused extensively on the outdoor environment and exposure to traffic-related pollutants, very little attention has been given to the indoor home environment and exposure to indoor allergens. Our study objectives were to determine whether there were differences in the presence of indoor allergen exposures by race/ethnicity and socioeconomic measures as well as to determine whether any relationship existed between neighborhood social characteristics and presence of indoor allergens among a diverse sample of households within Los Angeles.

METHODS

Study Sample

We examined the relationships between individual racial/ethnic and socioeconomic characteristics, neighborhood-level concentrated poverty and racial/ethnic composition, and indoor household allergens using data from the second wave of the Los Angeles Family and Neighborhood Survey (L.A.FANS). L.A.FANS is a longitudinal study designed to examine how neighborhoods impact the development and health of children, teens, and adults within Los Angeles County.[62,63] For our analyses, we utilized the data from participants that were initially selected into the first wave of L.A.FANS that were reinterviewed during the second wave. A total of 723 households which provided data on the current socioeconomic measures and indoor allergens during the second wave were included in the analyses.

Outcome Variables

Six measures of reported presence of indoor household allergens were examined in relation to individual- and neighborhood-level racial/ethnic and socioeconomic characteristics as our primary outcomes of interest. Our selection of each indoor household allergen was based on the strength of the evidence within the literature and included the reported presence of rats, mice, cockroaches, mold, pets, and smoking within the household.

For reported presence of rats, mice, and cockroaches, the primary caregiver was asked the following question during the primary caregiver module of the wave 2 interview: *In the last 12 months*, *have you had any of the following pests in your home*? 1. *Rats*; 2. *Mice*; 3. *Cockroaches*; 4. *Ants*; 5. *Spiders*; 6. *Termites*; 8. *No problems with pests*. The response to this question was further coded for each pest as a binary response of 1 if the respondent answered *yes* to reporting the presence of the pest and 0 if the respondent answered *no* to reporting the presence of the pest.

The presence of mold was categorized on the primary caregiver's response (1= yes, 0=no) to the following two questions: *In the last 12 months*, *has there been any mold or mildew on the walls*, *ceilings*, *or floors of your home*? and *In the last 12 months*, *has there been a moldy or musty smell on your home*? The presence of pets was based on the primary caregiver's response to the following two questions: *Do you have any pets that come inside the house or apartment at least part of the time*? and *What kind of pets do you have*? 1. *Dog*(*s*); 2. *Cat*(*s*); 3. *Bird*(*s*); 4. *Rabbit*(*s*); 5. *Guinea pig*(*s*), *gerbil*(*s*), *hamster*(*s*); 6. *Other* (*specify*). The presence of environmental tobacco smoke was based on the primary caregiver's response (1= yes, 0=no) to the following question: *Does anyone live here with you smoke cigarettes*, *cigars*, *or a pipe*?

Explanatory Variables

Individual-Level Characteristics Primary caregiver's race/ethnicity was provided by the primary caregiver within the roster module of L.A.FANS-2, based on the response to the following question: *What race or races would you say best describe you* (*please mark all that apply*)? 1. *Latino*; 2. *White*; 3. *African-American*, *Black*; 4. *Asian*; 5. *Pacific Islander*; 6. *Native American/American Indian*. The primary caregiver's response to this question was recoded into the following categories: (1) Non-Hispanic White, (2) Hispanic/Latino, (3) Non-Hispanic Black, and (4) Asian/ Other.

Primary caregiver's level of educational attainment was based on the primary caregiver's response to the following question: *How much school have you completed*? which included the following response options: 0. *None*; 1. *to* 11. *Grade* 1 *through* 11; 12. *High school graduate or completed GED*; 13. *Some vocational school*; 14. *Completed vocational school*; 15. *Some college*; 16. *Associates*' *degree* (*AA*); 17. *Bachelors*' *degree* (*BA*, *BS*); 18. *Some graduate or professional school* (*after completing college*); 19. *Completed graduate/professional degree*. Responses 0–11, 13, and 14 were recoded as (1) less than high school degree, response 12 was retained as (2) high school degree or equivalent, and responses 15–18 were recoded as (3) more than a high school degree.

For receipt of public assistance, primary caregivers were read a list of the types of income that many households receive and were asked to report (1=yes, 0=no) whether anyone in the household received any income from public assistance payments or foster care payments, including CalWORKS, county assistance, cash

assistance, TANF, AFDC, general relief, or other government payments for foster care, or other government welfare payments.

We assessed housing tenure based on the primary caregiver's response to the following question: *Is this* [*house/apartment*]: 1. *Rented by someone in this household*; 2. *Owned or being bought by someone living in the household*; *or* 3. *Neither*. Primary caregivers that responded neither were asked to provide a written response which was then recoded based on their response as to who owns or rents the property.

Neighborhood-Level Characteristics Neighborhood-concentrated poverty was assessed at the census tract level and was developed by Los Angeles County's Urban Research Division using state and county administrative data. For L.A.FANS tracts in the "very poor" poverty category, the average household poverty rate is 50 %; for those in the "poor" category, it is 30 %; and for those in the "non poor" category, it is 10 %.[63] Neighborhood racial/ethnic composition was based on a cluster analysis of the percent of the population in five race/ethnic groups for all census tracts. Census tracts were grouped into five categories based on their composition as follows: (1) high Asian/Pacific Islander, (2) predominantly White, (3) Latino and Black, (4) predominantly Latino, and (5) White and Other.

Statistical Methods

To examine associations between indoor allergen measures and individual and neighborhood sociodemographic characteristics, we conducted a series of two-level multilevel logistic regression models of 723 households at level 1 nested within 65 census tracts at level 2. The use of multilevel modeling allows us to account for natural and sampling-induced nesting within L.A.FANS, as well as model contextual heterogeneity.[64] As research has found that allergen levels within homes are influenced but not only individual but also neighborhood characteristics, single-level regression models would be inappropriate.[65] We first modeled the effects of individual race/ethnicity and socioeconomic status on the log odds of reporting various allergen measures and subsequently modeled the effects of neighborhood poverty and racial/ethnic composition independently, after controlling for individual factors for each outcome. Data manipulation and descriptive analyses were conducted using STATA 11; multilevel models were implemented using MLwiN. The research was approved by the Harvard School of Public Health Institutional Review Board (approval number P21104-102).

RESULTS

Respondent Characteristics

Table 1 presents the household allergen, demographic, and neighborhood characteristics of the analytic sample. The majority of households within the sample were Hispanic (66.1 %), followed by non-Hispanic Whites (17.6 %), and lastly non-Hispanic blacks and Asian/Pacific Islanders (8.3 and 8.0 %, respectively). The majority of primary caregivers had at least a high school degree or equivalent and one third of the sample were homeowners; approximately 9 % reported currently receiving public assistance. Among reported household allergens, the presence of cockroaches was most commonly reported. The presence of mold was reported

TABLE 1 Household allergen, sociodemographic, and neighborhood characteristics for L.A.FANS wave 2 participants ($n=723$)

Presence of household allergens	Number (%)	*Sociodemographic and neighborhood characteristics*	Number (%)
Presence of rats in home		Primary caregiver's race	
Yes	76 (10.5)	Non-Hispanic White	127 (17.6)
No	646 (89.4)	Hispanic/Latino	478 (66.1)
Presence of mice in home		Non-Hispanic Black	60 (8.3)
Yes	99 (13.7)	Asian/Other	58 (8.0)
No	624 (86.3)	Primary caregiver's education	
Presence of cockroaches in home		Less than high school	286 (39.6)
Yes	194 (26.8)	High school or equivalent	119 (19.5)
No	529 (73.2)	More than high school	316 (43.7)
Presence of mold or mildew in home		Receive public assistance	
Yes	144 (19.9)	Yes	64 (8.9)
No	577 (79.8)	No	658 (91.0)
Presence of pets in home		Home ownership	
Yes	278 (38.5)	Rented	448 (64.4)
No	444 (61.4)	Owned	243 (34.9)
Presence of dogs in house (of those with pets)		Poverty Strata	
Yes	193 (69.4)	Very poor	237 (32.8)
No	85 (30.6)	Poor	228 (31.5)
Presence of cats in house (of those with pets)		Not poor	258 (35.7)
Yes	91 (32.7)	Racial/ethnic composition	
No	187 (62.3)	High Asian/Pacific Islander	64 (8.9)
Current smoker		Predominantly White	101 (14.0)
Yes	76 (11.1)	Latino and Black	88 (12.1)
No	611 (88.9)	Predominantly Latino	353 (48.8)
		White and Other	117 (16.2)

among 20 % of respondents; the presence of mice was more frequently reported than rats. Nearly 39 % of respondents reported having a pet living in their household at least part time; the presence of a smoker within the household was reported among 11 % of respondents.

Table 2 displays the frequency of household allergens by individual race/ethnicity, socioeconomic measures, and neighborhood poverty and racial/ethnic composition. Hispanics households or households currently receiving public assistance most frequently reported the presence of cockroaches. Households where the primary caregiver had less than a high school degree reported higher percentages of mice, rats, and cockroaches. Higher percentages of mold and cockroaches were reported among renters compared to home owners. Households in very poor neighborhoods also reported the presence of mice, rats, and cockroaches more frequently than households in non-poor neighborhoods. Households within Latino and Black neighborhoods also reported the highest percentages of mice and cockroaches compared to homes categorized in other racial/ethnic composition groups.

TABLE 2 Presence of allergens in home by household sociodemographic and neighborhood characteristics

	Total (%)	Presence of allergens within home							
Household characteristics		Mice	Rats	Cockroaches	Mold	Pets	Dogs	Cats	Smoker
Primary caregiver's race									
Non-Hispanic White	127 (17.6)	10 (7.9)	14 (11.0)	11 (8.7)	23 (18.1)	84 (66.1)	61 (72.6)	35 (41.7)	28 (22.0)
Hispanic/Latino	478 (66.1)	71 (14.9)	59 (12.3)	164 (34.3)	99 (20.7)	149 (31.2)	106 (71.1)	31 (20.8)	93 (19.5)
Non-Hispanic Black	60 (8.3)	12 (20.0)	1 (1.7)	9 (15.0)	13 (21.7)	21 (35.0)	12 (57.1)	10 (47.6)	17 (28.3)
Asian/Other	58 (8.0)	6 (10.3)	2 (3.4)	10 (16.7)	9 (15.5)	24 (41.4)	14 (58.3)	15 (62.5)	9 (15.5)
Primary caregiver's education									
Less than high school	286 (39.6)	61 (21.3)	45 (15.7)	117 (40.9)	61 (21.3)	86 (30.1)	55 (64.0)	16 (18.6)	55 (19.2)
High school or equivalent	119 (19.5)	7 (5.9)	9 (7.6)	21 (17.6)	27 (22.7)	51 (42.9)	38 (74.5)	15 (29.4)	34 (28.6)
More than high school	316 (43.7)	30 (9.5)	22 (7.0)	55 (17.4)	55 (17.4)	140 (44.3)	100 (71.4)	60 (42.9)	57 (18.0)
Receive public assistance									
Yes	64 (8.9)	15 (23.4)	8 (12.5)	29 (45.3)	16 (25.0)	22 (34.4)	14 (63.6)	3 (13.6)	14 (21.9)
No	658 (91.0)	84 (12.8)	68 (10.3)	165 (25.1)	128 (19.5)	255 (38.8)	179 (70.2)	87 (34.1)	133 (20.2)
Home ownership									
Rented	448 (64.4)	68 (15.2)	45 (10.0)	149 (33.3)	107 (23.9)	119 (26.6)	66 (55.5)	30 (25.2)	88 (19.6)
Owned	243 (34.9)	31 (12.8)	31 (12.8)	43 (17.7)	37 (15.2)	159 (65.4)	127 (79.9)	61 (38.4)	59 (24.3)
Neighborhood characteristics									
Poverty strata									
Very poor	237 (32.8)	60 (25.3)	36 (15.2)	89 (37.6)	48 (20.3)	58 (24.5)	33 (56.9)	13 (22.4)	42 (17.7)
Poor	228 (31.5)	22 (9.6)	20 (8.8)	74 (32.5)	51 (22.4)	85 (37.3)	62 (72.9)	21 (24.7)	47 (20.6)
Not poor	258 (35.7)	17 (6.6)	20 (7.8)	31 (12.0)	45 (17.4)	135 (52.3)	98 (72.6)	57 (42.2)	58 (22.5)
Racial/ethnic composition									
High Asian/Pacific Islander	64 (8.9)	3 (4.7)	3 (4.7)	13 (20.3)	13 (20.3)	24 (37.5)	11 (45.8)	10 (41.7)	17 (26.6)
Predominantly White	101 (14.0)	8 (7.9)	12 (11.9)	9 (8.9)	22 (21.8)	69 (68.3)	49 (71.0)	29 (42.0)	17 (16.8)
Latino and Black	88 (12.1)	27 (30.7)	10 (11.4)	32 (36.4)	18 (20.5)	20 (22.7)	15 (75.0)	6 (30.0)	19 (21.6)
Predominantly Latino	353 (48.8)	56 (15.9)	42 (11.9)	124 (35.1)	72 (20.4)	115 (32.6)	74 (64.3)	26 (22.6)	68 (19.3)
White and Other	117 (16.2)	5 (4.3)	9 (7.7)	16 (13.7)	19 (16.2)	50 (42.7)	44 (88.0)	20 (40.0)	26 (22.2)

Multi-Level Logistic Regression Results

Individual-Level Racial/Ethnic and Socioeconomic Differences Within Table 3, adjusted odds ratios of reporting a presence of household allergens by race/ethnicity and individual socioeconomic measures are depicted. Hispanic households had a significantly higher odds of reporting cockroaches compared to non-Hispanic Whites (OR, 2.85; 95 % CI 1.38–5.88) even after adjusting for socioeconomic measures. Odds of reporting the presence of cockroaches was also higher among households of Asian, Pacific Islander, or Native American origin compared to non-Hispanic Whites (OR, 2.62; 95 % CI 1.02–6.73). Compared to non-Hispanic Whites, lower odds of reported presence of pets within the household were observed for Hispanics, non-Hispanic Blacks, and Asian households. After adjustment for socioeconomic measures, no racial/ethnic differences were observed in the odds of reporting mice, rats, mold, or smoking within the household. As displayed in Table 3, primary caregivers who had a high school degree reported an 80 % lower odds on the presence of mice and a 60 % lower odds on the presence of cockroaches compared to primary caregivers with less than a high school degree (OR, 0.19; 95 % CI 0.08–0.46 and OR, 0.39; 95 % CI 0.23–0.68, respectively). In addition to reporting lower odds of mice and cockroaches, primary caregivers with more than a high school degree also reported lower odds of rats within their households (OR, 0.43; 95 % CI 0.23–0.84) compared to those with less than a high school degree.

Primary caregivers currently receiving public assistance had more than twofold increase on the presence of cockroaches within their households, compared to primary caregivers not receiving public assistance (OR, 2.05; 95 % CI 1.16–3.62). Receipt of public assistance was not significantly associated with other indoor allergens. Compared to renters, home owners were more than 40 % less likely to report the presence of mice (OR, 0.58; 95 % CI 0.36–0.94) and nearly 70 % less likely to report the presence of cockroaches and mold within their households (OR, 0.32; 95 % CI 0.21–0.47 and OR, 0.31; 95 % CI 0.20–0.48, respectively). Home owners were also 60 % more likely to report having a pet, compared to renters.

Neighborhood-Level Concentrated Poverty and Racial/Ethnic Composition At the neighborhood level, neighborhood-concentrated poverty was also associated with increased odds of reporting mice; we observed that households in very poor neighborhoods had more than fourfold odds of reporting mice compared to households in non-poor neighborhoods, even after controlling for race/ethnicity and individual socioeconomic measures (Table 4). Households living in neighborhoods where the average household poverty rate was 50 % or more were nearly twice as likely of reporting cockroaches compared to households in non-poor neighborhoods (average household poverty rate is 10 % or less), which was marginally statistically significant after adjustment for covariates (OR, 1.90; 95 % CI 1.00–3.60).

Compared to households located in predominantly White neighborhoods, households located in Hispanic and Black neighborhoods had more than 4.5-fold increase in the odds of reporting mice, after adjustment of individual-level racial/ethnic and socioeconomic characteristics, and neighborhood concentrated poverty. Interestingly, statistically significant differences were observed by neighborhood racial/ethnic composition in the odds of reporting mold. Compared to households in predominantly White neighborhoods, households located in neighborhoods that were predominantly Latino, Latino and Black, or White and other all reported

TABLE 3 Adjusted odds ratios (ORs) and 95 % confidence intervals (CI) for reported presence of household allergen among L.A.FANS-2 households by race/ethnicity and individual socioeconomic measures

	Mice	Rats	Cockroaches	Mold	Pets	Smoker
Race/ethnicity[a]						
Non-Hispanic White	1.00	1.00	1.00	1.00	1.00	1.00
Hispanic	0.90 (0.39–2.03)	0.72 (0.34–1.54)	2.85 (1.38–5.88)*	0.78 (0.44–1.41)	0.27 (0.17–0.43)*	0.70 (0.41–1.22)
Non-Hispanic Black	2.28 (0.87–5.97)	0.13 (0.02–1.04)	1.24 (0.46–3.36)	0.85 (0.38–1.90)	0.30 (0.16–0.58)*	1.20 (0.58–2.47)
Asian/PI/NA	1.32 (0.45–3.88)	0.29 (0.06–1.33)	2.62 (1.02–6.73)*	0.90 (0.38–2.14)	0.36 (0.19–0.68)*	0.69 (0.30–1.58)
Primary caregiver education[b]						
Less than high school	1.00	1.00	1.00	1.00	1.00	1.00
High school	0.19 (0.08–0.46)*	0.47 (0.22–1.02)	0.39 (0.23–0.68)*	1.06 (0.63–1.80)	1.43 (0.90–2.27)	1.50 (0.90–2.50)
More than high school	0.34 (0.19–0.62)*	0.43 (0.23–0.84)*	0.48 (0.31–0.76)*	0.79 (0.49–1.26)	1.12 (0.75–1.68)	0.79 (0.49–1.29)
Public assistance[b]						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.72 (0.89–3.34)	1.24 (0.55–2.78)	2.05 (1.16–3.62)*	1.33 (0.72–2.43)	0.81 (0.47–1.42)	1.04 (0.56–1.96)
Home ownership[b]						
Renter	1.00	1.00	1.00	1.00	1.00	1.00
Owner	0.58 (0.36–0.94)*	0.89 (0.53–1.49)	0.32 (0.21–0.47)*	0.31 (0.20–0.48)*	1.63 (1.18–2.26)*	0.76 (0.51–1.12)

[a]Models adjusted for primary caregiver's education, receipt of public assistance, and home ownership

[b]Models adjusted for primary caregiver's race/ethnicity

*$p<0.05$

TABLE 4 Adjusted odds ratios (ORS) and 95 % confidence intervals (CI) for reported presence of household allergen among L.A.FANS households by neighborhood measures

	Mice	Rats	Cockroaches	Mold	Pets	Smoker
Neighborhood poverty						
Non-poor	1.00	1.00	1.00	1.00	1.00	1.00
Poor	1.53 (0.72-3.28)	0.89 (0.42-1.90)	1.81 (0.98-3.35)	0.98 (0.58-1.65)	0.75 (0.49-1.15)	0.76 (0.46-1.26)
Very poor	4.23 (1.98-9.03)*	1.57 (0.71-3.46)	1.90 (1.00-3.60)*	0.79 (0.44-1.41)	0.46 (0.28-0.74)	0.57 (0.33-1.00)
Neighborhood racial/ethnic composition						
Predominantly White	1.00	1.00	1.00	1.00	1.00	1.00
High Asian/PI	0.50 (0.11-2.24)	0.30 (0.07-1.36)	1.10 (0.34-3.55)	0.46 (0.18-1.16)	0.48 (0.23-1.01)	2.01 (0.84-4.82)
Latino and Black	4.54 (1.38-14.93)*	0.53 (0.15-1.91)	1.85 (0.59-5.79)	0.34 (0.13-0.88)*	0.27 (0.12-0.60)*	1.26 (0.50-3.20)
Predominantly Latino	2.01 (0.64-6.29)	0.48 (0.15-1.49)	1.54 (0.55-4.34)	0.33 (0.14-0.76)*	0.48 (0.24-0.92)*	1.20 (0.53-2.72)
White and Other	0.49 (0.14-1.76)	0.55 (0.19-1.63)	0.76 (0.26-2.23)	0.35 (0.16-0.80)*	0.52 (0.28-0.98)*	1.35 (0.62-2.90)

Models adjusted for primary caregiver's race/ethnicity, education, receipt of public assistance, home ownership status, and mutually adjusted for each neighborhood-level characteristic

*$p<0.05$

nearly 70 % lower odds of mold within their households. This difference was not observed among households located in neighborhoods of high Asian or Pacific Islander racial/ethnic composition compared to predominantly White households. Significantly lower odds of pet ownership were found among households located in neighborhoods that were predominantly Latino, Latino and Black, or White and other compared to households located in predominantly White neighborhoods. No statistically significant differences in the reported presence of rats, cockroaches, or smokers were observed by neighborhood racial/ethnic composition, after adjustment for individual-level racial/ethnic and socioeconomic characteristics, and neighborhood-concentrated poverty.

DISCUSSION

Our primary objectives were to examine whether differences in indoor allergen exposures existed by race/ethnicity, socioeconomic measures, and neighborhood-level characteristics. As these associations have been previously understudied, our study is an important contribution to the literature. While the majority of the literature has focused on cities in the Northeast and Midwest, studies have also shown that there is geographic variability in the frequency of certain indoor allergens, such as cockroach and dust mites.[43,66,67]Consistent with the literature, our study demonstrated a statistically significant difference in the reported presence of cockroach allergen among Hispanics compared to non-Hispanic Whites. Hispanics were no more likely than non-Hispanic Whites to report the presence of other allergens including mice, rats, or mold, contrary to prior studies. This may be due to geographic differences in allergen distributions in Los Angeles compared to other major cities, or there may be other factors, such as language or immigration status, which may influence reporting of allergens among Hispanics. Results from a recent study of housing affordability among L.A.FANS participants suggest that unauthorized Latino immigrants have the highest housing burden compared to non-Hispanic Whites, non-Hispanic Blacks, US-born Latinos, and authorized Latino immigrants within the sample.[68] As other studies among Latino immigrants have utilized either interviewer household observation or sample collection to assess household allergen exposure, it is possible that our observed patterns may be influenced by immigration or language issues in reporting.[38,39,46]

No significant differences in the reported presence of cockroaches within households were found between non-Hispanic Blacks and Whites, contrary to prior studies. However, our small sample size of non-Hispanic Blacks within the study ($n=60$) may have limited our ability to detect differences between the groups. Measures of socioeconomic status were significantly associated with a range of indoor allergen outcomes. Overall, primary caregiver's education appeared to have a protective effect on exposure to indoor allergens; receipt of public assistance was also associated with the increased report of cockroach exposure. Furthermore, home owners reported lower odds of mice, cockroaches, and mold compared to renters. These findings suggest that, irrespective of race/ethnicity, individuals with higher educational and socioeconomic levels may have access to healthier homes and resources to be able to prevent and mitigate exposure to allergens, such as integrated pest management or reduction of allergens in the home. As exposure to these allergens have been extensively studied within the asthma literature, reducing exposure to these allergens via programs and interventions targeted at those most at risk may be beneficial in reducing asthma disparities.[69–74]

At the neighborhood level, poverty was associated with higher odds of reporting cockroaches and mice, even after controlling for individual race/ethnicity and socioeconomic measures. Prior studies have found that poorer neighborhoods have increased crowding, poorer housing conditions, and higher rates of housing code violations which may result in increased indoor allergen exposures.[35,61,75,76] Previous studies have also found that cockroach and mice are more commonly sighted among lower socioeconomic neighborhoods. As low SES neighborhoods have also been found to have higher asthma prevalence rates, reducing exposure to cockroach and mice allergens may have important implications for reducing the asthma burden within these communities. Our study also found that the racial/ethnic composition of a neighborhood may have an impact on the presence of indoor allergens, irrespective of individual race/ethnicity and socioeconomic status. We found that households living in predominantly Latino, Latino and Black, and White and other neighborhoods reported lower presence of pets and mold compared to predominantly White neighborhoods. Although these findings are intriguing, as we are unaware of any other studies that have explicitly examined the impact of neighborhood racial/ethnic composition and only one other study has examined the association between neighborhood characteristics and indoor household allergens, it is difficult to assess whether our findings are consistent with prior studies.

The study had several limitations which should be considered including the cross-sectional nature of the study design and the use of self-report for allergen presence, rather than the collection of actual samples, which limited our ability to assess levels of exposure to each allergen. Although some studies have found home characteristics reporting a relatively weak predictor in the absence of the allergen, previous studies have found correlations between participant report of presence of indoor allergen and samples collected independently and reported presence of indoor allergens may be a viable alternative when collection of samples is not feasible[51,77–79].We also could not assess the presence of dust allergen as it was not included in home environment questionnaire. While dust exposure is an important predictor of asthma, all allergens included in the study have been found to play a role in asthma morbidity independent of presence of dust.

CONCLUSIONS

Our findings suggest several directions for additional research. Studies should continue to explore racial/ethnic and socioeconomic differences in household allergen exposures not only within inner city neighborhoods, but within suburban and rural areas, as well as in newer cities in the Southwest and Northwest; these studies could potentially highlight specific features of neighborhoods that commonly impact childhood asthma outcomes. Within diverse populations, greater attention should be paid to characteristics such as nativity, country of origin, and legal status which may help identify subgroups that are particularly vulnerable to poor housing conditions and toxic environmental exposures. Furthermore, additional research is needed examining the association between neighborhood characteristics and indoor household allergen exposures from a more comprehensive approach. While studies have previously linked neighborhood social features such as poverty, crime, and social capital as well as environmental and structural features such as traffic patterns and housing stock, it is likely that these features independently and simultaneously influence asthma outcomes. The examination of reporting and remediation practices related to fair housing law and housing code violations have been understudied with

respect to childhood asthma and warrant consideration along with other neighborhood features. As disparities in asthma onset and morbidity continue to persist, multilevel and multifactorial approaches in research, interventions, and policies are needed to reduce the burden of asthma within high-risk neighborhoods and populations.

ACKNOWLEDGMENTS

This research is supported by a National Institutes of Health Career Development Award (NHLBI K25 HL081275). National Heart, Lung and Blood Institute had no further role in study design, data collection, analysis, or interpretation in the writing of the report, or in the decision to submit the paper for publication. We would also like to thank RAND Corporation for allowing the use of L.A.FANS data.

REFERENCES

1. Akinbami LJ, Moorman JE, Bailey C, et al. Trends in asthma prevalence, health care use, and mortality in the United States, 2001–2010. *NCHS Data Brief*. 2012; 94: 1–8.
2. Akinbami LJ, Moorman JE, Garbe PL, Sondik EJ. Status of childhood asthma in the United States, 1980–2007. *J Pediatr*. 2009; 123(Suppl 3): S131–S145.
3. Akinbami LJ, LaFleur BJ, Schoendorf KC. Racial and income disparities in childhood asthma in the United States. *Ambul Pediatr*. 2002; 2(5): 382–287.
4. Bacon SL, Bouchard A, Loucks EB, Lavoie KL. Individual-level socioeconomic status is associated with worse asthma morbidity in patients with asthma. *Respir Res*. 2009; 10: 125.
5. Pearlman DN, Zierler S, Meersman S, Kim HK, Viner-Brown SI, Caron C. Race disparities in childhood asthma: does where you live matter? *J Natl Med Assoc*. 2006; 98(2): 239–247.
6. Bryant-Stephens T. Asthma disparities in urban environments. *J Allergy Clin Immunol*. 2009; 123(6): 1199–1206.
7. Gold DR, Wright R. Population disparities in asthma. *Annu Rev Public Health*. 2005; 26: 89–113.
8. Canino G, Koinis-Mitchell D, Ortega AN, McQuaid EL, Fritz GK, Alegria M. Asthma disparities in the prevalence, morbidity, and treatment of Latino children. *Soc Sci Med*. 2006; 63(11): 2926–2937.
9. Corburn J, Osleeb J, Porter M. Urban asthma and the neighbourhood environment in New York City. *Health Place*. 2006; 12(2): 167–179.
10. Gupta RS, Zhang X, Sharp LK, Shannon JJ, Weiss KB. Geographic variability in childhood asthma prevalence in Chicago. *J Allergy Clin Immunol*. 2008; 121(3): 639–645.
11. Cagney KA, Browning CR. Exploring neighborhood-level variation in asthma and other respiratory diseases: the contribution of neighborhood social context. *J Gen Intern Med*. 2004; 19(3): 229–236.
12. Juhn YJ, Sauver JS, Katusic S, et al. The influence of neighborhood environment on the incidence of childhood asthma: a multilevel approach. *Soc Sci Med*. 2005; 60(11): 2453–2464.
13. Vangeepuram N, Galvez MP, Teitelbaum SL, Brenner B, Wolff MS. The association between parental perception of neighborhood safety and asthma diagnosis in ethnic minority urban children. *J Urban Health*. 2012; 89(5): 758–768.
14. Subramanian SV, Kennedy MH. Perception of neighborhood safety and reported childhood lifetime asthma in the United States (US): a study based on a national survey. *PLoS One*. 2009; 4(6): e6091.

15. Wright RJ. Health effects of socially toxic neighborhoods: the violence and urban asthma paradigm. *Clin Chest Med*. 2006; 27(3): 413–421.
16. Wright RJ, Mitchell H, Visness CM, et al. Community violence and asthma morbidity in the Inner-City Asthma Study. *Am J Public Health*. 2004; 94: 625–632.
17. Sternthal MJ, Jun HJ, Earls F, Wright RJ. Community violence and urban childhood asthma: a multilevel analysis. *Eur Respir J*. 2010; 36(6): 1400–1409.
18. Jeffrey J, Sternfeld I, Tager I. The association between childhood asthma and community violence, Los Angeles County, 2000. *Public Health Rep*. 2006; 121(6): 720–728.
19. Wright RJ, Fisher EB. Putting asthma into context: community influences on risk, behavior, and intervention. In: Kawachi I, Berkman LF, eds. *Neighborhoods and Health*. New York, NY: Oxford University Press; 2003: 233–262.
20. Krieger J, Higgins DL. Housing and health: time again for public health action. *Am J Public Health*. 2002; 92(5): 758–768.
21. Weitzman M, Baten A, Rosenthal DG, Hoshino R, Tohn E, Jacobs DE. Housing and child health. *Curr Probl Pediatr Adolesc Health Care*. 2013; 43(8): 187–224.
22. Nguyen T, Lurie M, Gomez M, Reddy A, Pandya K, Medvesky M. The National Asthma Survey—New York State: association of the home environment with current asthma status. *Public Health Rep*. 2010; 125(6): 877–887.
23. Rosenfeld L, Chew GL, Rudd R, et al. Are building-level characteristics associated with indoor allergens in the household? *J Urban Health*. 2011; 88(1): 14–29.
24. Ahluwalia SK, Matsui EC. The indoor environment and its effects on childhood asthma. *Curr Opin Allergy Clin Immunol*. 2011; 11(2): 137–143.
25. Wilson J, Dixon SL, Breysse P, et al. Housing and allergens: a pooled analysis of nine US studies. *Environ Res*. 2010; 110(2): 189–198.
26. Matsui EC, Hansel NN, McCormack MC, Rusher R, Breysse PN, Diette GB. Asthma in the inner city and the indoor environment. *Immunol Allergy Clin North Am*. 2008; 28(3): 665–686.
27. Crain EF, Walter M, O'Connor GT, et al. Home and allergic characteristics of children with asthma in seven US urban communities and design of an environmental intervention: the Inner-City Asthma Study. *Environ Health Perspect*. 2002; 110(9): 939–945.
28. Diette GB, Hansel NN, Buckley TJ, et al. Home indoor pollutant exposures among inner-city children with and without asthma. *Environ Health Perspect*. 2007; 115(11): 1665–1669.
29. Northridge J, Ramirez OF, Stingone JA, Claudio L. The role of housing type and housing quality in urban children with asthma. *J Urban Health*. 2010; 87(2): 211–224.
30. Peters JL, Levy JI, Rogers CA, Burge HA, Spengler JD. Determinants of allergen concentrations in apartments of asthmatic children living in public housing. *J Urban Health*. 2007; 84(2): 185–197.
31. Suglia SF, Duarte CS, Sandel MT, et al. Social and environmental stressors in the home and childhood asthma. *J Epidemiol Community Health*. 2010; 64(7): 636–642.
32. Borrelli B, McQuaid EL, Wagener TL, Hammond SK. Children with asthma versus healthy children: Differences in secondhand smoke exposure and caregiver perceived risk. *Nicotine Tob Res*. 2013 Dec 4. (epub ahead of print).
33. Kit BK, Simon AE, Brody DJ, Akinbami LJ. US prevalence and trends in tobacco smoke exposure among children and adolescents with asthma. *Pediatrics*. 2013; 131(3): 407–414.
34. Wilson SE, Kahn RS, Khoury J, Lanphear BP. Racial differences in exposure to environmental tobacco smoke among children. *Environ Health Perspect*. 2005; 113(3): 362–367.
35. Rauh VA, Chew GR, Garfinkel RS. Deteriorated housing contributes to high cockroach allergen levels in inner-city households. *Environ Health Perspect*. 2002; 110(Suppl 2): 323–327.
36. Chew GL. Assessment of environmental cockroach allergen exposure. *Curr Allergy Asthma Rep*. 2012; 12(5): 456–464.

37. Chew GL, Carlton EJ, Kass D, et al. Determinants of cockroach and mouse exposure and associations with asthma in families and elderly individuals living in New York City public housing. *Ann Allergy Asthma Immunol*. 2006; 97(4): 502–513.
38. Cohn RD, Arbes SJ Jr, Jaramillo R, Reid LH, Zeldin DC. National prevalence and exposure risk for cockroach allergen in US households. *Environ Health Perspect*. 2006; 114(4): 522–526.
39. Esposito WA, Chew GL, Correa JC, Chillrud SN, Miller RL, Kinney PL. Quantitative measurement of airborne cockroach allergen in New York City apartments. *Indoor Air*. 2011; 21(6): 512–520.
40. Olmedo O, Goldstein IF, Acosta L, et al. Neighborhood differences in exposure and sensitization to cockroach, mouse, dust mite, cat, and dog allergens in New York City. *J Allergy Clin Immunol*. 2011; 128(2): 284–292.
41. Gent JF, Kezik JM, Hill ME, Tsai E, Li DW, Leaderer BP. Household mold and dust allergens: exposure, sensitization and childhood asthma morbidity. *Environ Res*. 2012; 118: 86–93.
42. Jones R, Recer GM, Hwang SA, Lin S. Association between indoor mold and asthma among children in Buffalo. *New York Indoor Air*. 2011; 21(2): 156–164.
43. Sahakian NM, Park JH, Cox-Ganser JM. Dampness and mold in the indoor environment: implications for asthma. *Immunol Allergy Clin North Am*. 2008; 28(3): 485–505.
44. Chew GL, Reardon AM, Correa JC, et al. Mite sensitization among Latina women in New York, where dust-mite allergen levels are typically low. *Indoor Air*. 2009; 19(3): 193–197.
45. Carlsten C, Ferguson A, Dimich-Ward H, et al. Association between endotoxin and mite allergen exposure with asthma and specific sensitization at age 7 in high-risk children. *Pediatr Allergy Immunol*. 2011; 22(3): 320–326.
46. Gent JF, Belanger K, Triche EW, Bracken MB, Beckett WS, Leaderer BP. Association of pediatric asthma severity with exposure to common household dust allergens. *Environ Res*. 2009; 109(6): 768–774.
47. Berg J, McConnell R, Milam J, et al. Rodent allergen in Los Angeles inner city homes of children with asthma. *J Urban Health*. 2008; 85(1): 52–61.
48. Cohn RD, Arbes SJ Jr, Yin M, Jaramillo R, Zeldin DC. National prevalence and exposure risk for mouse allergen in US households. *J Allergy Clin Immunol*. 2004; 113(6): 1167–1171.
49. Matsui EC. Role of mouse allergens in allergic disease. *Curr Allergy Asthma Rep*. 2009; 9(5): 370–375.
50. Salo PM, Jaramillo R, Cohn RD, London SJ, Zeldin DC. Exposure to mouse allergen in US homes associated with asthma symptoms. *Environ Health Perspect*. 2009; 117(3): 387–391.
51. Curtin-Brosnan J, Matsui EC, Breysse P, et al. Parent report of pests and pets and indoor allergen levels in inner-city homes. *Ann Allergy Asthma Immunol*. 2008; 101(5): 517–523.
52. Ownby DR. Pet dander and difficult-to-control asthma: the burden of illness. *Allergy Asthma Proc*. 2010; 31(5): 381–384.
53. Herr M, Just J, Nikasinovic L, et al. Influence of host and environmental factors on wheezing severity in infants: findings from the PARIS birth cohort. *Clin Exp Allergy*. 2012; 42(2): 275–283.
54. Bush RK. Indoor allergens, environmental avoidance, and allergic respiratory disease. *Allergy Asthma Proc*. 2008; 29(6): 575–579.
55. Heinrich J. Influence of indoor factors in dwellings on the development of childhood asthma. *Int J Hyg Environ Health*. 2011; 214(1): 1–25.
56. Arshad SH. Does exposure to indoor allergens contribute to the development of asthma and allergy? *Curr Allergy Asthma Rep*. 2010; 10(1): 49–55.

57. Carlsten C, Dimich-Ward H, Becker AB, et al. Indoor allergen exposure, sensitization, and development of asthma in a high-risk birth cohort. *Pediatr Allergy Immunol*. 2010; 21(4): e740–e746.
58. McHugh BM, MacGinnitie AJ. Indoor allergen sensitization and the risk of asthma and eczema in children in Pittsburgh. *Allergy Asthma Proc*. 2011; 32(5): 372–376.
59. Findley S, Lawler K, Bindra M, Maggio L, Penachio MM, Maylahn C. Elevated asthma and indoor environmental exposures among Puerto Rican children of East Harlem. *J Asthma*. 2003; 40(5): 557–569.
60. Teach SJ, Crain EF, Quint DM, Hylan ML, Joseph JG. Indoor environmental exposures among children with asthma seen in an urban emergency department. *Pediatrics*. 2006; 117(4 Pt 2): S152–S158.
61. Rosenfeld L, Rudd R, Chew GL, Emmons K, Acevedo-Garcia D. Are neighborhood-level characteristics associated with indoor allergens in the household? *J Asthma*. 2010; 47(1): 66–75.
62. Sastry N, Pebley AR. *Neighborhood and family effects on children's health in Los Angeles*. Los Angeles, CA: Labor and Population Working Paper: RAND Corporation; 2003.
63. Sastry N, Ghosh-Dastidar B, Adams J, et al. The design of a multilevel survey of children, families, and communities: The Los Angeles Family and Neighborhood Survey. *Soc Sci Res*. 2006; 35(4): 1000–1024.
64. Subramanian SV. The relevance of multilevel statistical models for identifying causal neighborhood effects. *Soc Sci Med*. 2004; 58: 1961–1967.
65. Wright RJ, Subramanian SV. Advancing a multilevel framework for epidemiologic research on asthma disparities. *Chest*. 2007; 132(5S): 757–769.
66. Lin S, Jones R, Munsie JP, Nayak SG, Fitzgerald EF, Hwang SA. Childhood asthma and indoor allergen exposure and sensitization in Buffalo, New York. *Int J Hyg Environ Health*. 2012; 215(3): 297–305.
67. Simons E, Curtin-Brosnan J, Buckley T, Breyesse P, Eggleston PA. Indoor environmental differences between inner city and suburban homes of children with asthma. *J Urban Health*. 2007; 84(4): 577–590.
68. McConnell ED. Who has housing affordability problems? Disparities in housing cost burden by race, nativity and legal status in Los Angeles. *Race Soc Probl*. 2013; 5(3): 173–190.
69. Krieger J. Home is where the triggers are: increasing asthma control by improving the home environment. *Pediatr Allergy Immunol Pulmonol*. 2010; 23(2): 139–145.
70. Krieger J, Jacobs DE, Ashley PJ, et al. Housing interventions and control of asthma-related indoor biologic agents: a review of the evidence. *J Public Health Manag Pract*. 2010; 16(5 Suppl): S11–S20.
71. McConnell R, Milam J, Richardson J, et al. Educational intervention to control cockroach allergen exposure in the homes of Hispanic children in Los Angeles: results of the La Casa study. *Clin Exp Allergy*. 2005; 35(4): 426–433.
72. Platts-Mills TA. Allergen avoidance in the treatment of asthma: problems with the meta-analyses. *J Allergy Clin Immunol*. 2008; 122(4): 694–696.
73. Sheehan WJ, Rangsithienchai PA, Wood RA, et al. Pest and allergen exposure and abatement in inner-city asthma: a work group report of the American Academy of Allergy, Asthma & Immunology Indoor Allergy/Air Pollution Committee. *J Allergy Clin Immunol*. 2010; 125(3): 575–581.
74. Sterling YM. Impact of the environment on asthma control. *J Community Health Nurs*. 2012; 29(3): 143–153.
75. Krieger JW, Song L, Takaro TK, Stout J. Asthma and the home environment of low-income urban children: preliminary findings from the Seattle-King County Health Homes Project. *J Urban Health*. 2000; 77: 50–67.
76. Sandel M, Wright RJ. When home is where the stress is: expanding the dimensions of housing that influence asthma morbidity. *Arch Dis Child*. 2006; 91: 942–948.

77. Hansel NN, Eggleston PA, Krishnan JA, et al. Asthma-related health status determinants of environmental control practices for inner-city preschool children. *Ann Allergy Asthma Immunol*. 2006; 97: 409–417.
78. Matsui EC, Eggleston PA, Buckley TJ, et al. Household mouse allergen exposure and asthma morbidity in inner-city preschool children. *Ann Allergy Asthma Immun*. 2006; 97: 514–520.
79. Chew GL, Burge HA, Dockery DW, Muilenberg ML, Weiss ST, Gold D. Limitations of a home characteristics questionnaire as a predictor of indoor allergen levels. *Am J Respir Crit Care Med*. 1998; 157(5 Pt1): 1536–1541.