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Individual, Housing, and Neighborhood Correlates of Asthma among Young Urban Children

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ABSTRACT *Using data from a large cohort of urban children, this study identified multilevel correlates of asthma to determine whether neighborhood attributes remain associated with asthma after adjustment for individual level and immediate housing characteristics. A cross-sectional analysis was conducted using data from the Fragile Families and Child Well-being Study and its substudy, the In-Home Longitudinal Study of Pre-Schooled Age Children (n=1,784). The primary outcome was asthma diagnosis by age 5. Sociodemographic measures were assessed via telephone survey, housing and block conditions recorded via direct observation, and neighborhood characteristics came from geocoded census tract data. After multivariable adjustment, non-Hispanic Black, Puerto Rican, or other Hispanic race, child's lack of insurance coverage, male gender, presence of allergies, the exterior condition of a child's home, mother's educational attainment, and the percent of the neighborhood population with a bachelor's degree remained significantly associated with having received an asthma diagnosis by age 5. The authors identified sociodemographic and economic factors at the individual, household, and neighborhood level which are correlates of childhood asthma in urban areas. After adjustment for more proximal characteristics, the effects of all neighborhood markers were minimal, with the exception of neighborhood education.*

KEYWORDS *Asthma, Young children, Neighborhood, Social, Economic*

Abbreviations: FFCW – Fragile Families and Child Well-being; FPL – Federal poverty level; IQR – Interquartile range; LSPAC – In-Home Longitudinal Study of Pre-Schooled Age Children

INTRODUCTION

Both an individual's socioeconomic status and their larger social environment have consistently been shown to be associated with morbidity and mortality across a wide range of diseases.[1] Childhood asthma is a particularly pertinent example of a disease that is "socially patterned"[2,3]: A body of research has shown that asthma is disproportionately shouldered by socially disadvantaged populations, particularly

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minority children living in low-income urban areas.[2,4–8] Studies conducted among populations of urban children have explored correlates of childhood asthma in efforts to identify the different levels at which social, psychological, and physical factors in the urban environment increase children's risk for asthma. Parent's race,[9,10] child's gender,[9,10] poverty, insurance status,[11] housing conditions,[10,12,13] and indoor allergen exposures[14–16] have all been associated with asthma in children, and some studies have also linked neighborhood level socioeconomic or housing characteristics to asthma.[11,17] Because there are very few published studies which include individual, immediate housing, and neighborhood level data in the same model, questions still remain as to whether characteristics of the neighborhood environment contribute directly to the development and exacerbation of asthma, or whether they are only representative of unmeasured characteristics more proximal to the individual. Using data from a large cohort of urban children, we sought to identify individual, housing, and neighborhood correlates of asthma and to determine whether neighborhood effects remained important after adjustment for individual level and immediate housing characteristics.

MATERIALS AND METHODS

Study Design and Population

We conducted a cross-sectional analysis using data at multiple levels: individual, housing, block, and neighborhood. Data came from the Fragile Families and Child Well-being (FFCW) Study and one of its substudies, the In-Home Longitudinal Study of Pre-Schooled Age Children (LSPAC). The FFCW is a prospective birth cohort of children from 20 large cities across the USA: Details on the study design have been previously described.[18] In brief, mothers were recruited from 75 hospitals during their stay for childbirth. Within each hospital, births were randomly sampled from birth logs, and non-marital births were over-sampled. Mothers were screened for eligibility and were included if they were able to complete the baseline interview in English or Spanish, if the father of the newborn was living, and if they were not planning to place the child up for adoption. Of those identified as eligible for the parent FFCW cohort, 86 % agreed to participate, and baseline interviews were conducted during mothers' hospital stay. Follow-up data have been collected via telephone survey at 1, 3, and 5 year follow-ups. At the 3-year FFCW visit, the child's main caregiver was offered participation in the LSPAC substudy, a collaborative FFCW study designed to examine how parental resources influence children under the age of 5. If the mother agreed, an in-home assessment was conducted in which data on family routines, nutrition, stress, exposure to violence, child behavior, and conditions of the immediate home and block were recorded. The institutional review boards of all birth hospitals, Princeton University, and the Robert Wood Johnson Medical School approved the data collection procedures.

To be eligible for the current analysis, a participant had to have complete census tract data, as well as complete measurements on all measures of the interior and exterior home, sociodemographics, and clinical characteristics. Of the 4,898 mothers who completed the FFCW baseline survey, 4,049 completed the FFCW 5-year survey, and 3,001 participated in the 5-year LSPAC study. Of these 3,001, a subset of 2,031 had complete geocoded census tract data available, and 1,927 and 1,954, 1,979, and 1,977 had complete census tract data and complete data on the condition of the block, the physical assessment of the home interior, the social

assessment of the home interior, and the assessment of the home exterior, respectively. In total, 1,784 participants contributed data to this analysis.

Individual-Level Measures

Asthma outcomes ascertained in the FFCW were based on standard questions from the National Health Interview Survey (NHIS). The main outcome variable for the current analysis was diagnosis of asthma by age 5. At the 5-year telephone survey, mothers were asked, "Has a doctor or other health professional ever told you that your child has asthma?," and a positive response to this question determined case status. In sensitivity analyses, we also examined whether results of multivariate models differed when asthma attack prevalence was used as an outcome, using the NHIS question, "During the past 12 months has your child had an episode of asthma or an asthma attack?"

Sociodemographic and clinical measures were collected as part of the mother's telephone survey and included household income as percentage of the federal poverty level (FPL), mother's race/ethnicity, education level and marital status, child's gender, and symptoms of hay fever or allergy in the last 12 months. A child's health insurance status was assessed by asking whether a child was covered by Medicaid and, if not, whether or not the child was covered by private health insurance. For the current analysis, if a mother answered no to both of these questions, the child was coded as having no insurance coverage. Access to medical care was measured by asking whether or not the child had a usual place for routine health care, such as regular check-ups. Mothers were then asked to identify the routine health care setting as either a doctor's office, hospital/outpatient clinic, or other clinic. Smoking status was assessed by asking whether or not there were one or more people who smoked inside the household where the child lived.

Conditions of child's housing and immediate block were assessed by trained interviewers during the 5-year LSPAC visits using a checklist based on validated measures from The Home Observation for Measurement of the Environment interior and exterior subscales from the Project on Human Development in Chicago Neighborhoods.[19,20] For the purpose of the current study, home exteriors were considered to be in "poor condition" if they had evidence of peeling paint, crumbling walls, or broken windows. Home interiors were considered to be in "poor condition" (physical) if they had evidence of cracks or holes in the walls/ceiling, or evidence of rodents, and in "poor condition" (social) if they had evidence of dark, cluttered, crowded, noisy, or unclean interiors. Blocks were designated in "poor condition" if they had interviewer-observed evidence of graffiti, litter, vacant homes, or nearby homes in poor condition.

Neighborhood Level Measures

Sociodemographic characteristics of a child's larger neighborhood environment were measured via US 2000 census tract variables corresponding to the geographic coordinates of the residence in which a mother lived at the time of the baseline interview. Census tract measures considered for inclusion in the analysis included percentage of population with at least a high school education, percentage of civilian labor force unemployed, percentage of households on public assistance, percentage of housing units vacant, percentage of housing units renter-occupied, percentage of population non-Hispanic Black, percentage of population with a bachelor's degree or higher, and percentage of families below the FPL. Using data reduction techniques, we identified three census tract variables (percentage of population with

at least a high school education, percentage of civilian labor force unemployed, and percentage of households on public assistance) which were highly collinear with at least one other census tract variable and thus not included in multivariate analyses.

Statistical Analysis

Characteristics were calculated as frequencies for categorical variables and median and interquartile range (IQR) for continuous variables. Unadjusted odds ratios and 95 % confidence intervals were calculated for the association of each characteristic with asthma diagnosis by age 5. Preliminary analyses showed that 72.7 % of census tracts had only one participant per tract, and initial analyses using random effects models showed that clustering of observations by census tract was negligible. Thus, logistic regression analysis using maximum likelihood estimation was chosen as the primary analytic technique for multivariate modeling. Only variables which were associated with asthma at the $p<0.10$ level in bivariate analyses were considered for inclusion in multivariate models. Five separate multivariate logistic regression models were constructed to examine the extent to which effect estimates changed (i.e., attenuation of effect) when individual, housing, and neighborhood characteristics were included in a stepwise fashion. Model 1 included demographic and clinical (individual) characteristics only, model 2 included child's housing characteristics only, and model 3 included census tract variables and block characteristics only. Model 4 included individual and child's housing characteristics in the same model, but no block or census tract characteristics, and model 5 included individual, child's housing, block, and census tract characteristics. All analyses were performed using SAS version 9.1 (Cary, NC, USA).

RESULTS

Detailed data on individual, housing, and neighborhood characteristics of children and their mothers are shown in Table 1. By design, the 1,784 mothers of children included in the FFCW study[18] and the current analysis were majority non-white, unmarried, and had lower educational and income levels. Using direct observation, 20.9 % of children's home exteriors and 22.5 % of the blocks that children resided on were classified as being in poor condition and 11.0 and 37.4 % of children's home interiors were classified in poor physical and poor social condition, respectively. On average, the census tracts that mothers of children resided in at baseline were characterized by a low proportion of residents who had attained a bachelor's degree and a sizable proportion of housing properties which were designated as rental units. The overall prevalence of asthma diagnosis by 5 years of age was 21.1 %.

Unadjusted and adjusted odds ratio's for the association of each characteristic with asthma diagnosis by age 5 are shown in Tables 2 and 3. Asthma rates differed by mother's race: 12.6 % of white, 23.7 % of black, and 40.4 % of Puerto Rican mothers reported that their child had ever been diagnosed with asthma. Adjustment for individual-level indicators of income, education, and health insurance only minimally attenuated the relationship between race and asthma diagnosis (Table 2, model 1), and further adjustment for housing and neighborhood level characteristics (Table 3, models 4 and 5) had little additional impact on the effect estimates for mother's race. Asthma rates also differed by household income: Rates were 15.9, 21.4, and 23.0 % for children whose household incomes were 300 %, 100–299 %, or below (<100 %) the FPL, respectively. However, after adjustment for other

TABLE 1 Sociodemographic, clinical, and housing and neighborhood characteristics of the study population

	Number (percent)
Asthma diagnosis, age 5	376 (21.1 %)
Demographic and clinical characteristics	
Mother's race/ethnicity	
Non-Hispanic White	342 (19.2 %)
Non-Hispanic Black	953 (53.1 %)
Puerto Rican	57 (3.2 %)
Mexican	248 (13.9 %)
Other Hispanic	134 (7.5 %)
American Indian/Asian	47 (2.6 %)
Mother's marital status (at 5-year follow-up)	
Unmarried	1,217 (68.2 %)
Married	566 (31.7 %)
Mother's education level	
College graduate or graduate school	174 (9.8 %)
Some college or technical school	434 (24.4 %)
High school grad or GED	476 (26.7 %)
<High school graduate	698 (39.2 %)
Household income (% of FPL)	
300+%	321 (18.0 %)
100–299 %	677 (38.0 %)
0–99 %	786 (44.1 %)
Child's gender	
Female	857 (48.0 %)
Male	927 (52.0 %)
Child's allergies	
Allergy symptoms in last 12 months	1741 (97.6 %)
No allergy symptoms in last 12 months	42 (2.4 %)
Child's insurance coverage	
Private insurance	612 (34.3 %)
Medicaid	1,066 (59.8 %)
No insurance coverage	106 (5.9 %)
Child has a usual place for routine health care	
Yes	1743 (97.8 %)
No	40 (2.2 %)
≥1 smokers inside the child's home	736 (41.3 %)
Housing conditions (child's home)	
Exterior of home in poor condition[a]	373 (20.9 %)
Interior of home in poor condition (physical)[b]	196 (11.0 %)
Interior of home in poor condition (social)[c]	668 (37.4 %)
Neighborhood conditions (immediate block environment)	
Block in poor condition[d]	401 (22.5 %)
Neighborhood characteristics (census tract)	
% 25+ population with bachelor's degree, median (IQR)	10.9 % (6.0 %, 20.6 %)
% occupied housing units rentals, median (IQR)	48.2 % (32.7 %, 67.1 %)
% housing units vacant, median (IQR)	6.8 % (4.1 %, 11.8 %)
% population non-Hispanic Black, median (IQR)	38.9 % (5.1 %, 87.4 %)
% Families <federal poverty level, median (IQR)	17.8 % (8.0 %, 29.2 %)

[a]Home exteriors in "poor condition" had interviewer-observed evidence of peeling paint, crumbling walls, or broken windows

[b]Home interiors in "poor condition" (physical) had interviewer-observed evidence of cracks or holes in the walls/ceiling, or evidence of rodents

[c]Home interiors in "poor condition" (social) had interviewer-observed evidence of dark, cluttered, crowded, noisy, or unclean interiors

[d]Blocks in "poor condition" had interviewer-observed evidence of graffiti, litter, vacant homes, or nearby homes in poor condition

TABLE 2 Individual, housing, and neighborhood characteristics associated with asthma diagnosis by age 5

	Unadjusted OR (95% CI)	Model 1[e] Adj. OR (95% CI)	Model 2[f] Adj. OR (95% CI)	Model 3[g] Adj. OR (95% CI)
Demographic and clinical characteristics				
Race/ethnicity (mother)				
Non-Hispanic White	1.00 (ref)	1.0 (ref)	–	–
Non-Hispanic Black	2.16 (1.52, 3.08)**	1.88 (1.28, 2.76)**	–	–
Puerto Rican	4.70 (2.53, 8.73)**	4.34 (2.25, 8.37)**	–	–
Mexican	1.50 (0.95, 2.34)	1.28 (0.78, 2.09)	–	–
Other Hispanic	2.27 (1.37, 3.77)*	1.97 (1.16, 3.33)*	–	–
American Indian/Asian	1.43 (0.63, 3.26)	1.25 (0.54, 2.93)	–	–
Education level (mother)				
College graduate/graduate school	1.00 (ref)	1.00 (ref)	–	–
Some college or technical school	3.09 (1.74, 5.49)**	2.50 (1.35, 4.65)**	–	–
High school grad or GED	2.89 (1.63, 5.12)**	2.00 (1.04, 3.82)*	–	–
<High school graduate	3.20 (1.83, 3.59)**	2.18 (1.14, 4.17)*	–	–
Household income (% of FPL)				
300+%	1.00 (ref)	1.00 (ref)	–	–
100–299 %	1.44 (1.02, 2.04)*	0.97 (0.63, 1.52)	–	–
0–99 %	1.58 (1.12, 2.22)**	1.00 (0.63, 1.52)	–	–
Male gender (child)	1.63 (1.29, 2.07)**	1.71 (1.35, 2.17)**	–	–
Allergy symptoms in last 12 months (child)	2.62 (1.40, 4.90)**	2.97 (1.55, 5.69)**	–	–
Insurance coverage (child)				
Private insurance	1.00 (ref)	1.00 (ref)	–	–
Medicaid	1.36 (1.05, 1.75)*	1.04 (0.77, 1.42)	–	–
No insurance coverage	2.04 (1.28, 3.25)**	1.86 (1.13, 3.05)*	–	–
≥1 smokers inside the child's home	1.25 (0.99, 1.57)	1.16 (0.91, 1.48)	–	–
Housing conditions (child's home environment)				
Exterior in poor condition[a]	1.79 (1.38, 2.32)**	–	1.61 (1.19, 2.18)*	–
Interior in poor condition (physical)[b]	1.63 (1.17, 2.26)**	–	1.14 (0.78, 1.67)	–
Interior in poor condition (social)[c]	1.38 (1.10, 2.26)**	–	1.18 (0.92, 1.51)	–

Neighborhood conditions (immediate block environment)				
Block in poor condition[d]	1.61 (1.12, 2.17)*	–	–	1.30 (0.95, 1.78)
Neighborhood characteristics (census tract)				
% 25+ population with bachelor's	0.07 (0.02, 0.19)**	–	–	0.09 (0.03, 0.34)**
% occupied housing units rentals	1.51 (0.93, 2.46)	–	–	1.04 (0.52, 2.03)
% housing units vacant	10.81 (2.37, 49.24)**	–	–	2.07 (0.33, 13.08)
% population non-Hispanic Black	1.56 (1.16, 2.11)**	–	–	1.05 (0.73, 1.50)
% families <federal poverty level	4.02 (1.90, 8.50)**	–	–	0.85 (0.23, 3.14)
R^2		0.0711	0.0182	0.0286
AIC		1,781.92	1,827.01	1,818.42

OR odds ratio, *CI* confidence interval, *FPL* federal poverty level

*$P<0.05$; **$P<0.01$

[a]Home exteriors in "poor condition" had interviewer-observed evidence of peeling paint, crumbling walls, or broken windows

[b]Home interiors in "poor condition" (physical) had interviewer-observed evidence of cracks or holes in the walls/ceiling, or evidence of rodents

[c]Home interiors in "poor condition" (social) had interviewer-observed evidence of dark, cluttered, crowded, noisy, or unclean interiors

[d]Blocks in "poor condition" had interviewer-observed evidence of graffiti, litter, vacant homes, or nearby homes in poor condition

[e]Model 1 includes demographic and clinical characteristics only

[f]Model 2 includes housing conditions only

[g]Model 3 includes census tract and block characteristics only

TABLE 3 Individual, housing, and neighborhood characteristics associated with asthma diagnosis by age 5

	Model 4[e] Adj. OR (95% CI)	Model 5[f] Adj. OR (95% CI)
Demographic and clinical characteristics		
Race/ethnicity (mother)		
Non-Hispanic White	1.0 (ref)	1.0 (ref)
Non-Hispanic Black	1.81 (1.23, 2.66)**	1.88 (1.17, 3.02)**
Puerto Rican	4.50 (2.3, 8.68)**	4.53 (2.29, 8.96)**
Mexican	1.33 (0.81, 2.18)	1.32 (0.80, 2.17)
Other Hispanic	2.01 (1.18, 3.42)*	1.93 (1.12, 3.32)*
American Indian/Asian	1.27 (0.54, 2.98)	1.45 (0.61, 3.47)
Education level (mother)		
College graduate/graduate school	1.0 (ref)	1.0 (ref)
Some college or technical school	2.49 (1.34, 4.62)**	2.16 (1.14, 4.06)*
High school grad or GED	1.95 (1.02, 3.74)*	1.66 (0.85, 3.21)
<High school graduate	2.09 (1.09, 4.00)*	1.75 (0.91, 3.40)
Household income (% of FPL)		
300+%	1.0 (ref)	1.0 (ref)
100–299 %	1.08 (0.69, 1.70)	1.20 (0.76, 1.89)
0–99 %	1.07 (0.71, 1.61)	1.17 (0.78, 1.76)
Male gender (child)	1.63 (1.29, 2.07)**	1.71 (1.35, 2.17)**
Hay fever/allergies (child)	1.68 (1.33, 2.14)**	1.68 (1.32, 2.14)**
Insurance coverage (child)		
Private insurance	1.0 (ref)	1.0 (ref)
Medicaid	1.03 (0.76, 1.40)	1.01 (0.74, 1.38)
No insurance coverage	1.83 (1.11, 3.00)*	1.76 (1.07, 2.90)*
≥1 smokers inside the child's home	1.12 (0.87, 1.43)	1.08 (0.84, 1.39)
Housing conditions (child's home environment)		
Exterior in poor condition[a]	1.47 (1.08, 2.01)*	1.46 (1.06, 2.00)*
Interior in poor condition (physical)[b]	1.09 (0.74, 1.62)	1.10 (0.74, 1.63)
Interior in poor condition (social)[c]	1.07 (0.82, 1.39)	1.06 (0.81, 1.38)
Neighborhood conditions (immediate block environment)		
Block in poor condition[d]	–	1.06 (0.76, 1.50)
Neighborhood characteristics (census tract)		
% 25+ population with bachelor's degree	–	0.17 (0.04, 0.70)*
% occupied housing units rentals	–	–
% housing units vacant	–	1.88 (0.27, 13.14)
% population non-Hispanic Black	–	0.81 (0.48, 1.35)
% families <federal poverty level	–	1.21 (0.30, 4.87)
R^2	0.0804	0.0901
AIC	1,776.76	1,775.198

OR odds ratio, *CI* confidence interval, *FPL* federal poverty level

*$P<0.05$; **$P<0.01$

[a]Home exteriors in "poor condition" had interviewer-observed evidence of peeling paint, crumbling walls, or broken windows

[b]Home interiors in "poor condition" (physical) had interviewer-observed evidence of cracks or holes in the walls/ceiling, or evidence of rodents

[c]Home interiors in "poor condition" (social) had interviewer-observed evidence of dark, cluttered, crowded, noisy, or unclean interiors

[d]Blocks in "poor condition" had interviewer-observed evidence of graffiti, litter, vacant homes, or nearby homes in poor condition

[e]Model 4 includes demographic and housing characteristics only

[f]Model 5 includes individual-level sociodemographic, housing characteristics, interviewer observed/participant reported neighborhood characteristics, and census tract level neighborhood variables

individual-level sociodemographic characteristics, the association between household poverty level and asthma diagnosis was no longer significant (Table 2, model 1). The prevalence of asthma diagnosis was 17.5, 23.2, and 30.2 % among children with private health insurance coverage, Medicaid, and those lacking health insurance coverage, respectively. After adjustment for sociodemographic characteristics, the relationship between Medicaid coverage and asthma diagnosis was no longer significant (Table 2, model 1). However, lack of insurance coverage remained a significant predictor of asthma even after full adjustment (Table 3, model 5).

The prevalence of asthma diagnosis was 23.2, 21.4, 22.6, and 8.6 %, among children of mothers who had completed college or graduate school, had some college or technical school, had graduate from high school, and had not completed high school, respectively. After adjustment for sociodemographic characteristics only (Table 2, model 1) and sociodemographic and housing characteristics (Table 3, model 4), the relationship between education level and diagnosis of asthma was attenuated but remained significant. However, when neighborhood characteristics were added to the model, the effect estimates for individual-level education were attenuated further, and only one comparison (some college/technical school vs. college graduate/graduate school) remained significant (Table 3, model 5).

Rates of asthma were significantly higher among children whose home exteriors and interiors were categorized as being in "Poor condition," compared to those whose were not (29.5 vs. 18.9 %, $P<0.01$ for home exteriors, 29.1 vs. 20.2 %, $P<0.01$ for home interiors (physical), and 24.6 vs. 19.1 %, $P<0.01$ for home interiors (social)). However, after adjustment for the exterior condition of a child's home, the home interior measures no longer remained significantly related to diagnosis of asthma (Table 1, model 2). The relationship between exterior housing characteristics and asthma diagnosis was attenuated but remained significant after multivariate adjustment for sociodemographic (Table 2, model 4) and neighborhood characteristics (Table 2, model 5).

Prevalence of asthma was higher among children living on blocks with graffiti, litter, vacant homes, or deteriorating streets, compared to children living on blocks with no evidence of these characteristics (24.9 vs. 15.9 %, $P<0.01$). After adjustment for neighborhood level census tract variables, physical conditions of the immediate block were no longer significant (Table 2, model 3). While four of the five census tract variables considered in the analysis were associated with asthma diagnosis in unadjusted analyses (Table 2), after controlling for other neighborhood characteristics simultaneously, only one census tract variable, percentage of adult population with a bachelor's degree, remained significantly related to asthma diagnosis (Table 2, model 3). The protective effect of this census tract variable was attenuated but remained significant in the final model which simultaneously controlled for individual and housing characteristics (Table 3, model 5).

In the full multivariable model (Table 3, model 5), mother's race/ethnicity, child's insurance coverage, child's gender, allergies, the physical condition of a child's exterior home, and the percent of the population with a bachelor's degree remained significantly associated with asthma diagnosis by the age of 5. These six variables were also retained when forwards and backwards model selection techniques were used. No interactions were detected between any of the explanatory variables included in the multivariate model. In additional analyses, multivariate adjustment for additional potential confounders (child's BMI, and mother's prenatal care) did not impact the results of the models shown in Table 2 substantially—thus, these variables were not included in final models due to reduction in sample size from

missing data. Alternative methods for modeling neighborhood measures (combining census tract variables in to a scale score) and sensitivity analyses substituting asthma attack prevalence as the outcome variable in multivariable models identified comparable sets of predictors.

DISCUSSION

Using data from a large cohort of young urban children, we used a multilevel framework to identify individual, housing, and neighborhood markers of asthma diagnosis by age 5. Our study extends upon previous findings[11,12] providing evidence that in a cohort of urban youth, socioeconomic factors as well as selected characteristics of the immediate physical and broader social environment are associated with the diagnosis of asthma. While previous researchers have highlighted the fact that forces acting at the neighborhood level (e.g., markers of poverty including crime, vacant housing, and/or increased rental units) could be important contributors to childhood asthma,[3,11,21–26] data from the current study shows that after adjustment for individual-level socioeconomic characteristics and/or directly observed housing and block conditions, all of the neighborhood level characteristics considered—except education level—were no longer significant. These results suggest that in many cases, neighborhood level associations may be able to be reduced to characteristics more proximal to the individual.

Notably, our analyses showed that the educational level of adults in the neighborhood in which a child resides is associated with asthma diagnosis, even after adjustment for individual-level education or income, mother's race, immediate housing environment, and other traditional risk factors. At the individual level, lower parental education level has been linked to higher levels of asthma triggers such as environmental tobacco smoke.[27] However, data linking neighborhood education level with asthma is sparse. The protective influence of increased education level in a child's neighborhood may represent an important construct for increased access to collective resources and capital,[28] medical care, or healthy behaviors, reduced stress, or decreased allergens. For example, a greater proportion of individuals with higher education may indicate greater social capital and therefore the potential to improve neighborhood conditions and reduce neighborhood disorder[29]—which may in turn reduce an individual's negative psychophysiological response to the larger neighborhood environment. Further exploration of this association would be an important follow-up to this analysis.

Our findings of increased rates of asthma among children of Black and Puerto Rican mothers replicate those from several other studies which have found high prevalence rates of asthma among minority children living in urban areas, even after adjustment for socioeconomic indicators and measures of the physical or social environment.[10,11,22,30] It is possible that racial disparities in asthma that are seen both in this FFCW sample and across the literature may be due to geographic residence: Urban white children are less likely than minority residents to live in deteriorating central city areas than black or Hispanic children and correspondingly less likely to experience heightened levels of allergen and particulate exposures along with community and individual stressors which increase vulnerability to these exposures.[30] Another explanation is the potential for "differential diagnosis" by race, i.e., minority children may be more likely to receive a "diagnostic label" of asthma when presenting with a wheezing episode because of biases held by health care providers.[31,32] It is also notable that the prevalence of asthma in our sample

was particularly high among Puerto Rican children. This finding is consistent with previous literature: Surveillance programs and epidemiologic studies have consistently shown that Puerto Ricans have higher rates of both wheezing and asthma diagnosis than non-Hispanic White[33] and other US minorities,[34] and this relationship has shown to persist even after controlling for important confounders or socioeconomic measures and housing conditions.[8,10,35]

In the current study, lack of health insurance coverage was associated with asthma, even after adjustment for individual, housing, and neighborhood factors. One proposed explanation for this finding is that uninsured children who have temporary and episodic interactions with the healthcare system (e.g., assessments by unfamiliar providers in urgent care settings) may be more likely to be given a diagnosis of asthma for a wheezing episode to ensure treatment.[4,31] This may be have occurred in our study population, where children lacking insurance coverage were more likely to report their usual place of health care as a walk-in clinic, ER care center, or "other" clinic (rather than a doctor's office or private clinic) and to not have not been seen by a doctor or nurse for an illness in the last 12 months.

In unadjusted analyses, the prevalence of asthma was higher among children living in homes with evidence of deteriorating conditions—both indoor and outdoor. Previous research has linked deteriorating housing conditions to higher loads of indoor allergens—thus children living in deteriorated housing could have increased exposure, sensitization, and risk of developing asthma. In New York City, Rauh *et al.* showed that levels of cockroach allergens and cockroach sightings were associated with degree of housing disrepair and deterioration.[36] In a similar study carried out in Boston, Peters et al. found that homes with clutter, lack of cleanliness, and holes in the wall or ceiling had elevated levels of cockroach allergen compared to other urban homes.[37] Serious housing code violations have also been linked to increased cockroach and mice allergen levels in the home.[38]

Strengths and Limitations

This study has several strengths. The large sample size and broad dataset of individual, household, and neighborhood variables allowed for examination of the relative impact of numerous markers of economic disadvantage. Restriction of the sample to low-income, urban youth allowed for identification of *which* factors in the urban environment might be used as markers for high rates of asthma. Further, data available simultaneously at the individual and neighborhood level (i.e., mother's education and education level of neighborhood) allowed for close examination of whether contextual level factors are exerting an influence in addition to individual-level variables. Finally, because this analysis uses data from the FFCW 5-year visit, "ever diagnosis of asthma" may be a more accurate measure than previous analyses based on the 3-year data.[11,12]

We were limited by self-report data in assessment of the outcome variable and had no ability to confirm with medical records. However, we do not have reason to believe that parents' report of asthma diagnosis in their child would have occurred differentially. Despite adjustment for a broad array of socioeconomic indicators, unmeasured or residual confounding may have existed due to a priori categorization of variables such as education or income. The assumption was made that the conditions of a child's home or neighborhood were consistent over time. Also, while direct measurements of allergen loads would have helped to confirm whether children's housing and neighborhood characteristics were associated with diagnosis of asthma via increased exposure to allergens and particulates, results from previous

research have repeatedly established links between housing deterioration and increased allergen and/or particulates. Finally, because our analysis was conducted among a subsample of the FFCW and unmarried mothers were over-sampled, the focus of this analysis was to investigate associations present within an urban cohort rather than to generate asthma prevalence rates which were nationally representative of the general US population.

In conclusion, this analysis adds new empirical data to the proposed conceptual framework that social and economic factors acting at the individual, household, and neighborhood level may contribute to childhood asthma in a cohort of urban youth. Mother's race, child's insurance coverage, home conditions, and educational attainment remained consistent markers for childhood asthma, even after multivariable adjustment. Our results also showed that while neighborhood characteristics were significant in unadjusted analyses, after adjustment for more proximal characteristics, the effects of all neighborhood markers—except educational level—were minimal.

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