Low Birthweight and Asthma Among Young Urban Children

Lenna Nepomnyaschy, PhD, and Nancy E. Reichman, PhD

Objectives. We assessed whether the association between low birthweight and early childhood asthma can be explained by an extensive set of individual- and neighborhood-level measures.

Methods. A population-based sample of children born in large US cities during 1998–2000 was followed from birth to age 3 years (N = 1803). Associations between low birthweight and asthma diagnosis at age 3 years were estimated using multilevel models. Prenatal medical risk factors and behaviors, demographic and socioeconomic characteristics, and neighborhood characteristics were controlled.

Results. Low-birthweight children were twice as likely as normal birthweight children to have an asthma diagnosis (34% vs 18%). The fully adjusted association (OR = 2.36; $P < .001$) was very similar to the unadjusted association (OR = 2.48; $P < .001$). Rates of renter-occupied housing and vacancies at the census tract–level were strong independent predictors of childhood asthma.

Conclusions. Very little of the association between low birthweight and asthma at age 3 can be explained by an extensive set of demographic, socioeconomic, medical, behavioral, and neighborhood characteristics. Associations between neighborhood housing characteristics and asthma diagnosis in early childhood need to be further explored. (*Am J Public Health.* 2006;96:1604–1610. doi:10.2105/AJPH.2005.079400)

Childhood asthma has nearly doubled in the last 2 decades to become one of the most common chronic childhood conditions in the United States, from 3.7% of children in 1980 to 6.9% in 1995.[1,2] Although family history of asthma and atopy is highly predictive of asthma in children,[3] most researchers agree that environmental factors must play an important role, because genetic variation alone cannot explain such a steep increase in childhood asthma rates.[3–5] Childhood asthma is associated with increased rates of doctor visits, hospitalizations, school absenteeism, parental work absenteeism, child activity limitations, and child disability.[6–8] Children living in inner-city neighborhoods are at especially high risk for asthma.[9,10]

The rates of low birthweight (<2500 g) and very low birthweight (<1500 g) have also increased in the US to 7.8% and 1.5%, respectively—the highest levels in 3 decades. The increases are largely, but not entirely, attributable to an increase in the prevalence of multiple births.[11] As a result of substantial advances in neonatal care technology, low-birthweight infants are much less likely than they were in 1980 to die before their first birthday.[12] Low-birthweight infants who survive, particularly those who are very low birthweight, are at high risk for respiratory disorders.[12]

A number of studies have found strong associations between low birthweight and subsequent poor lung function,[13–26] although not all have focused specifically on children or asthma. The mechanisms underlying the association are not clearly understood. The uterine environment may play a role, through nutritional intake and development of the immune and respiratory systems.[26,27] Neonatal respiratory support interventions may contribute to disturbances in subsequent pulmonary function.[15] The observed associations between low birthweight and childhood asthma are also thought to reflect, at least in part, poverty-related factors such as inner-city residence and poor housing quality, which have been associated with both conditions.[10,28–35]

We analyzed a sample of children born in large US cities between 1998 and 2000 and followed the children through age 3 years. We used this sample to assess the extent to which the association between low birthweight and childhood asthma in the urban population can be explained by an extensive set of demographic and socioeconomic characteristics, maternal medical risk factors, and prenatal behaviors that are associated with both conditions. We also explored the extent to which neighborhood characteristics explain the association.

METHODS

Data

Births were randomly selected from birth logs in 75 hospitals in 20 US cities with populations greater than 200 000 as part of the Fragile Families and Child Wellbeing study, a national longitudinal birth cohort survey that is representative of the US urban population. Nonmarital births (births to unmarried parents) were oversampled. Mothers were approached, while still in the hospital after giving birth, by a professional survey interviewer and screened for eligibility. If eligible, the mothers were asked to participate in a national survey about the conditions and capabilities of new parents, their relationships, and their children's well-being. Mothers were eligible for the study if they and their baby's father were at least 18 years old, although this age restriction did not apply in approximately one third of the hospitals, where they were considered emancipated minors; if they were able to complete the interview in either English or Spanish; if the father of the newborn was living; and if they were not planning to place the child for adoption. Informed consent was administered. A total of 4898 mothers (86% of those eligible) were interviewed between the spring of 1998 and the fall of 2000.[36]

Mothers were reinterviewed when the child was approximately 1 year old and then again at 3 years. Of the 4898 mothers who completed baseline interviews, 3319 (68%) completed interviews 3 years later, at which time they were asked whether the child had ever been diagnosed with asthma. Additional information was collected from hospital medical records in 17 of the 20 cities from the baseline survey. Housing characteristics and poverty rates of the census tracts in which the mothers resided were obtained from the 2000 US Census and merged to the individual records according to the mothers' baseline addresses. Of the 2994 cases for which medical record data were available, 2032 (68%) had 3-year follow-up data. Of those, 1845 had complete data on all analysis variables. An additional 42 mothers with multiple births were excluded, leaving an analysis sample of 1803 births. A comparison of mothers in the full baseline sample, the medical records sample, the 3-year follow-up sample, and our analysis sample indicate no differences between samples. The samples were compared on the basis of maternal age, education, marital status, race/ethnicity, place of birth, and low-birthweight delivery from the baseline survey.

Measures

The mother was asked at the 3-year follow-up interview whether a doctor or health care professional had ever told her that her child has asthma. The child was characterized as having been diagnosed with asthma if the mother responded affirmatively to this question. Mothers of children who were diagnosed with asthma were asked whether the child had an asthma attack and whether the child had visited an emergency room or other urgent care facility because of asthma in the past 12 months. Birthweight was obtained from the medical records and coded as a dichotomous variable indicating whether the child was low birthweight (<2500 g). Mothers' reports of their children's birthweight in the baseline interview were used in the case of 11 children for whom birthweight was not available from the medical records.

Past studies have demonstrated strong associations between socioeconomic status and child health outcomes,[37–39] particularly low birthweight[12] and asthma.[10,29,40,41] Therefore, detailed demographic and socioeconomic characteristics that may explain the relation between birthweight and asthma were included in the analyses. The demographic characteristics (all taken from the mother's baseline interview) included categorical variables for the mother's age (younger than 20 years, 20–34 years, and 35 years or older [the reference category]), race/ethnicity (non-Hispanic White [the reference category], non-Hispanic Black, Mexican origin, Hispanic of other origin, and non-Hispanic other), and dichotomous indicators for US-born, first birth, marital birth, and the mother having lived with both biological parents at age 15. The socioeconomic status variables (all taken from the mother's baseline interview) were the mother's level of education (less than high school [the reference category], high-school graduate, and more than high school), and whether the mother worked in the year before the birth. We also included a dichotomous indicator for whether the birth was not privately insured (i.e., the birth was funded through Medicaid or the mother had no health insurance). This variable was included as a proxy for the mother's poverty status, not as a measure of access to or quality of health care.

Medical and behavioral risk factors that are associated with both birthweight and childhood asthma[5,42–48] were included in the analyses. The medical risk factors (assessed from the hospital medical records) included dichotomous indicators for history of maternal asthma, preexisting diabetes, gestational diabetes, preexisting hypertension, pregnancy-related hypertension, and prenatal mental illness. Also included were dichotomous indicators for maternal cigarette smoking and prenatal illicit drug use during pregnancy (ascertained from the medical records, baseline interviews, or both). We included an indicator for first trimester prenatal care from the baseline survey.

A growing body of research has shown a strong association between housing characteristics and child health.[30,49–54] A number of neighborhood housing characteristics at the census-tract level were included in the analyses; they were based on the mother's residence at baseline when the child was born. The characteristics included the percent of vacant housing units, the percent of units lacking complete plumbing, the percent of renter-occupied units, the percent of units built before 1940, and the mean number of people per household. Also included was a measure of neighborhood poverty (the percent of families in the census tract with incomes below poverty level).

Statistical Analyses

Characteristics of the sample were examined by low-birthweight status, and separately, by the outcome (asthma diagnosis at age 3). Two-tailed *t* tests for comparison of means (and χ^2 tests for categorical variables) were conducted using Stata Version 8.0 statistical software (Stata CorpLP, College Station, Tex). MLwiN version 1.1 statistical software (Centre for Multilevel Modelling Information, University of Bristol, Bristol, England) was used to estimate multilevel variance components models, which account for the clustering of observations within census tracts and produce unbiased estimates for both individual- and tract-level variables. We specified 2-level models with individuals nested within census tracts. The first model included low birthweight only. The second added individual-level demographic, socioeconomic, medical, and behavioral risk factors. The third model included neighborhood poverty and housing characteristics, in addition to low birthweight. The fourth model included all of the individual and neighborhood variables, in addition to low birthweight. Odds ratios and *P* values are presented for the multivariate analyses, as are the between-tract variances in asthma diagnosis. Numerous alternative model specifications and measures were examined to assess the robustness of the results.

RESULTS

Nineteen percent of the children in our sample had been diagnosed with asthma by approximately age 3. This figure is higher than the national rate discussed in our introduction. This was expected, because our sample is representative of births in large urban areas. Children who were low birthweight were almost twice as likely as those who were not low birthweight to have an asthma diagnosis by 3 years of age (34% vs 18%) (Table 1). Mothers of low-birthweight children were more likely than those of normal birthweight children to be non-Hispanic Black (65% vs 48%), younger than 20 years old (27% vs 19%), 35 years old or older (14% vs 9%), US-born (94% vs 84%), and hypertensive

TABLE 1—Characteristics of Sample, by Birthweight and Asthma Diagnosis, N = 1803

	Normal Birthweight	Low Birthweight	*P*	No Asthma Diagnosis	Asthma Diagnosis	*P*
Asthma diagnosis, no. (%)	287 (18)	59 (34)	<.001			
Low birthweight, no. (%)				113 (8)	59 (17)	<.001
Demographic characteristics						
Race/ethnicity, no. (%)						
Non-Hispanic White	316 (19)	31 (18)	<.001	308 (21)	39 (11)	<.001
Non-Hispanic Black	788 (48)	112 (65)		693 (48)	207 (60)	
Mexican origin	299 (18)	15 (9)		270 (19)	44 (13)	
Other Hispanic	162 (10)	13 (8)		130 (9)	45 (13)	
Non-Hispanic other	66 (4)	1 (1)		56 (4)	11 (3)	
Age, y, no. (%)						
< 20	316 (19)	46 (27)	.002	280 (19)	82 (24)	.122
20–34,	1175 (72)	102 (59)		1039 (71)	238 (69)	
≥ 35	140 (9)	24 (14)		138 (9)	26 (8)	
US-born, no. (%)	1374 (84)	162 (94)	.001	1216 (83)	320 (92)	<.001
First birth, no. (%)	612 (38)	73 (42)	.209	563 (39)	122 (35)	.241
Male child, no. (%)	844 (52)	95 (55)	.389	726 (50)	213 (62)	<.001
Age of child at 3 y interview, mo, mean ±SD	39 ±3.3	38 ±3.1	.077	39 ±3.3	38 ±3.4	.412
Marital birth, no. (%)	400 (25)	28 (16)	.016	378 (26)	50 (14)	<.001
Socioeconomic status						
Educational level, no. (%)						
Less than high school	577 (35)	69 (40)	.270	501 (34)	145 (42)	.003
High-school graduate	494 (30)	54 (31)		438 (30)	110 (32)	
More than high school	560 (34)	49 (28)		518 (36)	91 (26)	
Lived with both parents at age 15, no. (%)	684 (42)	61 (35)	.103	628 (43)	117 (34)	.002
Medicaid paid for birth, no. (%)	1053 (65)	139 (81)	<.001	925 (63)	267 (77)	<.001
Maternal medical and behavioral factors						
Diabetes, no. (%)	18 (1)	2 (1)	.945	13 (1)	7 (2)	.071
Gestational diabetes, no. (%)	88 (5)	3 (2)	.037	67 (5)	24 (7)	.075
Hypertension, no. (%)	51 (3)	10 (6)	.064	43 (3)	18 (5)	.038
Gestational hypertension, no. (%)	115 (7)	30 (17)	<.001	114 (8)	31 (9)	.488
Mother has asthma, no. (%)	210 (13)	32 (19)	.034	163 (11)	79 (23)	<.001
Used illicit drugs during pregnancy, no. (%)	166 (10)	33 (19)	<.001	152 (10)	47 (14)	.094
Smoked cigarettes during pregnancy, no. (%)	339 (21)	69 (40)	<.001	324 (22)	84 (24)	.419
Mental illness, no. (%)	156 (10)	29 (17)	.003	141 (10)	44 (13)	.095
Prenatal care in first trimester, no. (%)	1302 (80)	126 (73)	.044	1146 (79)	282 (82)	.239
Neighborhood characteristics						
Percentage families below poverty, mean ±SD	18.8 ±13.3	20.7 ±15.5	.080	18.2 ±13.3	22.4 ±14.1	<.001
Percentage housing units vacant, mean ±SD	8.5 ±7.1	9.5 ±6.6	.075	8.2 ±6.7	10.2 ±8.2	<.001
Percentage housing units that are rentals, mean ±SD	49.8 ±22.5	50.1 ±22.6	.862	48.8 ±22.7	53.9 ±21.4	<.001
Percentage housing units built before 1940, mean ±SD	22.0 ±20.7	23.0 ±20.2	.570	21.6 ±20.6	24.3 ±21.0	.028
Percentage housing units with incomplete plumbing, mean ±SD	1.7 ±2.3	2.0 ±2.9	.107	1.7 ±2.3	2.0 ±2.6	.009
No. persons per household, mean ±SD	2.82 ±0.6	2.73 ±0.5	.031	2.82 ±0.6	2.81 ±0.5	.757

Note. Three hundred forty-six children (19%) had an asthma diagnosis and 172 (10%) were low birthweight. *P* values are from χ^2 tests (race/ethnicity, age, education) and 2-tailed *t* tests (all other measures).

(17% vs 7% for gestational hypertension). They also were much more likely than mothers of normal birthweight children to have a history of asthma (19% vs 13%), have smoked cigarettes during pregnancy (40% vs 21%), have used illicit drugs during pregnancy (19% vs 10%), have a mental illness (17% vs 10%), and to have had a Medicaid-funded or uninsured birth (81% vs 65%). They were less likely to be of Mexican origin (9% vs 18%), 20 to 34 years old (59% vs 72%), and to have been married at the time of the birth (16% vs 25%). Mothers of low-birthweight children were more likely to live in census tracts with higher vacancy rates, fewer people per nonvacant household, and higher poverty rates.

Many of these characteristics also are associated with asthma diagnosis, in the same direction. Mothers of children who were diagnosed with asthma by age 3 were more likely than mothers of children without an asthma diagnosis to be non-Hispanic Black (60% vs 48%), Hispanic of non-Mexican origin (13% vs 9%), US-born (92% vs 83%), have less than a high-school education (42% vs 34%), have preexisting diabetes (2% vs 1%), have preexisting hypertension (5% vs 3 %), have a history of asthma (23% vs 11%), and to have had a Medicaid-funded or uninsured birth (77% vs 63%). They also lived in census tracts with higher vacancy rates, higher poverty rates, and higher proportions of housing that were renter-occupied, built before 1940, and had incomplete plumbing. They also were less likely to be non-Hispanic White (11% vs 21 %), of Mexican origin (13% vs 19%), married (14% vs 26 %), have education beyond high school (26% vs 36%), and have lived with both biological parents at age 15 (34% vs 43%). The children diagnosed with asthma by 3 years were more likely to be male (62% vs 50%) than those not diagnosed with asthma.

Very little of the strong association between low birthweight and childhood asthma at age 3 can be explained by the demographic, socioeconomic, medical, behavioral, and neighborhood characteristics included in our analyses (Table 2). When the full set of covariates is included (Model 4; OR = 2.36; $P < .001$) the association is only 5% lower than that of the unadjusted model (Model 1;

OR= 2.48; $P<.001$). Mothers who were Black, of non-Mexican Hispanic origin, US-born, had a male child, had gestational diabetes, had asthma themselves, had prenatal care in the first trimester, or had Medicaid or no insurance were significantly more likely to have a child diagnosed with asthma than mothers without these characteristics, after birthweight and other covariates were controlled. Living in census tracts with greater proportions of vacant housing and renter-occupied housing was positively associated with likelihood of asthma diagnosis. The associations between both of the housing measures and asthma were large, although the association between the housing vacancy rate and asthma was of borderline statistical significance. A 10 percentage point increase in the proportion of vacant houses in the census tract increased by 20% the likelihood of being diagnosed with asthma (Model 4; OR= 1.02; P=.096). A 10 percentage point increase in the proportion of renter-occupied housing in the census tract increased by 10% the likelihood of being diagnosed with asthma (Model 4; OR= 1.01; P=.046). Neither cigarette smoking during pregnancy nor prenatal illicit drug use was associated with childhood asthma when low birthweight and the other covariates were controlled. The associations between individual-level variables and asthma (Model 2) and between neighborhood-level variables and asthma (Model 3) remained virtually unchanged when both sets of variables were included (Model 4). Although multilevel modeling is the conceptually correct statistical approach for this type of analysis, there was in fact little clustering of observations within neighborhoods in our data. There were on average 1.5 births per census tract, and 69% of the 1174 tracts contained only 1 birth (data not shown).

We assessed the robustness of the results to alternative definitions of asthma, birthweight-related measures, and model specifications (results not shown, but available from the authors upon request). The outcomes included maternal reports of whether the child had an asthma attack (10% of sample), an asthma-related emergency room visit by the child (8%), and both of these (7%). The association of low birthweight with these outcomes was strong and significant regardless of model specification, and the housing vacancy rate was an even stronger and statistically significant predictor of these outcomes than it was of asthma diagnosis. Models of asthma diagnosis and low birthweight were estimated with each covariate alone, covariates significantly associated with asthma diagnosis at $P<.05$ (Table 1), and city of residence, in addition to the full set of covariates. These models indicated strong, statistically significant, and robust associations between low birthweight and asthma, between housing vacancy rates and asthma, and between rates of owner-occupied housing and asthma.

The association between low birthweight and asthma was reduced by at most 10%, and that was when the only covariate in the model was Medicaid-funded or uninsured birth. Similarly robust associations were found among models that used categorical rather than continuous definitions of the neighborhood measures, that dropped very low-birthweight (<1500g) children from the sample, that dropped the 11 cases for which birthweight data were not available from the medical records, and that excluded mothers under age 18 (for whom education is confounded with maternal age). Finally, logistic regression models that did not account for clustering of births in certain neighborhoods produced results virtually identical to the multilevel results presented.

DISCUSSION

We found a strong association between low birthweight and asthma among 3-year-old children who were born in large US cities. This association remained virtually unchanged after an extensive set of maternal demographic, socioeconomic, medical, and behavioral risk factors that are associated with both low birthweight and asthma were controlled, as well as measures of neighborhood housing quality and poverty at the census-tract level. The results were robust to alternate model specifications and measures and underscore that low birthweight is a strong independent predictor of childhood asthma diagnosis among young urban children.

A number of previous studies of children in the United States[13,15,24] and other countries[16,19,20,22,23,25,26] have found persistent associations between low birthweight and asthma, after a variety of sociodemographic and medical risk factors were controlled. Several other studies, most of which focused on children in other countries, have not found an association. The latter set of studies generally examined older children or adolescents,[27,55–59] or used small nonrepresentative samples.[60–63] No previous studies of the association between low birthweight and asthma in the US used prospective population-based data and were able to control for independently documented maternal health status or neighborhood housing characteristics. Analysis of data from a national longitudinal survey that have been merged with detailed prenatal medical record data and neighborhood characteristics, puts our study in a good position to identify potential confounders.

The analyses incorporated measures of prenatal substance use from both medical records and self-reports, leading to much lower rates of false negatives than when using survey reports alone. Prenatal cigarette smoking was associated with low birthweight but only weakly associated with a childhood asthma diagnosis. It was not associated with asthma when low birthweight was controlled and did not explain any of the association between low birthweight and asthma.

Census tract–level rates of renter-occupied housing units and vacancies were strong predictors of childhood asthma, even when low birthweight, demographic characteristics, socioeconomic status, maternal medical risk factors, prenatal behaviors, neighborhood poverty, and city of residence were controlled (in the last case, in alternate specifications). Neither housing characteristic explained the association between low birthweight and childhood asthma, but each was a strong and significant independent predictor of asthma. High rates of renter-occupied housing units may reflect residential instability or poorly maintained housing, both of which are associated with poor health outcomes, including asthma.[64,65]

The tract-level housing vacancy measure we used may serve as a proxy for the individual's own housing quality or may be a

TABLE 2—Multilevel Model Estimates of Associations Between Low Birthweight and Asthma Diagnosis

	Model 1		Model 2		Model 3		Model 4	
	OR	*P*	OR	*P*	OR	*P*	OR	*P*
Low birthweight	2.48	<.001	2.30	<.001	2.45	<.001	2.36	<.001
Demographic characteristics								
Race/ethnicity								
Non-Hispanic White			1.00				1.00	
Non-Hispanic Black			1.89	.003			1.64	.028
Mexican origin			1.61	.084			1.50	.171
Other Hispanic			2.63	<.001			2.31	.004
Non-Hispanic other			2.21	.055			2.14	.067
Age, y								
< 20			1.03	.858			1.03	.872
20–34			1.00				1.00	
≥ 35			0.87	.604			0.88	.625
US-born			2.63	.001			2.80	<.001
First birth			0.85	.290			0.88	.390
Male child			1.63	<.001			1.64	<.001
Age of child at 3-year interview			1.00	.880			1.00	.850
Marital birth			0.81	.303			0.84	.384
Socioeconomic status								
Educational level								
Less than high school			1.00				1.00	
High-school graduate			0.77	.110			0.80	.163
More than high school			0.74	.104			0.78	.193
Lived with both parents at 15			0.92	.544			0.94	.691
Medicaid paid for birth			1.49	.019			1.43	.038
Maternal medical and behavioral factors								
Diabetes			1.89	.213			1.91	.212
Gestational diabetes			1.99	.013			1.95	.016
Hypertension			1.55	.168			1.51	.199
Gestational hypertension			0.93	.764			0.94	.785
History of asthma			2.14	<.001			2.11	<.001
Used illicit drugs during pregnancy			1.09	.689			1.06	.793
Smoked during pregnancy			0.89	.493			0.88	.442
Mental illness			1.15	.510			1.16	.504
Prenatal care in first trimester			1.53	.012			1.54	.011
Neighborhood characteristics								
Percentage families below poverty					1.01	.067	1.00	<.001
Percentage housing units vacant					1.03	.011	1.02	.096
Percentage housing units that are rentals					1.01	.134	1.01	.046
Percentage housing units built before 1940					1.00	<.001	1.00	<.001
Percentage housing units with incomplete plumbing					0.97	.382	0.98	.467
Mean no. persons per household					1.08	.544	1.14	.383
Model diagnostics								
Between-tract variance (SE)	0.10 (0.16)		0.19 (0.17)		0.15 (0.16)		0.21 (0.17)	

Note. OR = odds ratio. Data are for 1803 individuals nested within 1174 census tracts. Model 1: Low birthweight only; Model 2: Low birthweight and individual characteristics; Model 3: Low birthweight and neighborhood characteristics; Model 4: Low birthweight, individual and neighborhood characteristics.

"spillover effect" from proximate housing. Previous research has shown that asthma is associated with exposure to indoor allergens from mold, rats, and cockroaches.[49,66–71] Vacant houses and apartments are more likely than nonvacant housing units to harbor vermin, and to have leaky windows, roofs, and pipes that may contribute to damp environments.[50] The tract-level housing vacancy measure may also serve as an index of neighborhood safety, with higher vacancy rates representing less safe environments and possibly less interaction with neighbors, less exercise, and less fresh air.

Although numerous studies (several of which are cited above) have found associations between individuals' own housing characteristics and asthma, very few have considered neighborhood housing conditions. A few studies of asthma in the United Kingdom[53,72] used the Townsend deprivation index, which includes neighborhood-level measures of crowding and proportion of owner-occupied housing. These studies found associations between this index and asthma, but did not examine crowding and owner-occupied housing separately. To our knowledge, only 1 other study has examined associations between specific neighborhood housing conditions and asthma.[73] That study found that neighborhood stability, measured using the proportions of residents living in the same house since 1985 and of owner-occupied housing, was associated with asthma and breathing problems among adults in Chicago. No studies have been able to control for housing quality at both the individual and neighborhood levels. Our finding that high vacancy and renter-occupied housing rates are associated with asthma among young children suggests that research is needed to determine whether characteristics of adjacent or nearby housing are associated with asthma above and beyond those of individuals' own housing units.

Our study was subject to some limitations. First, it relied on mothers' reports of whether their 3-year-old children had been diagnosed with asthma. Second, a definitive diagnosis of asthma is difficult to make at age 3, as wheezing in early childhood is often misclassified as asthma.[74–76] Third, individual-level characteristics and neighborhood poverty may be imperfect proxies for socioeconomic status.

Fourth, the neighborhood measures correspond to the mothers' census tract at the time of birth, not necessarily where the child lived from birth through age 3 (this, however, would likely bias the results downward). Fifth, although we have shown that the association between low birthweight and childhood asthma persists even when a wide range of factors that had the potential to explain the association were controlled, we cannot rule out the possibility that the association is confounded by differential diagnosis. Low-birthweight children may have conditions other than asthma that require medical attention, and therefore may be more likely than normal birthweight children to be diagnosed with asthma by age 3. Other childhood health conditions were not included in the analyses. It is also possible that other unmeasured characteristics, such as differential diagnosis by race or ethnicity, underlie some of the observed association between low birthweight and asthma diagnosis.

In summary, very little of the strong association we found between low birthweight and maternal reports of asthma diagnosis among young children could be explained by a comprehensive set of well-measured demographic, socioeconomic, prenatal medical, prenatal behavioral, and neighborhood characteristics. Ours is the first study to document independent associations of childhood asthma with neighborhood-level housing vacancy rates and rates of renter-occupied housing. These associations need to be replicated and further explored. ■

About the Authors

Lenna Nepomnyaschy is with the Columbia University School of Social Work, New York, NY. Nancy E. Reichman is with the Department of Pediatrics at Robert Wood Johnson Medical School, New Brunswick, NJ.

Requests for reprints should be sent to: Lenna Nepomnyaschy, Columbia University School of Social Work, 1255 Amsterdam Ave, Room 718, New York, NY 10027 (e-mail: ln77@columbia.edu).

This article was accepted October 21, 2005.

Contributors

Both authors shared in the conception of the study, design of the analysis, interpretation of the findings, and writing.

Acknowledgments.

This research was supported by the National Institute of Child Health and Human Development (grant R01HD35301). Jennifer Borkowski and Ofira Schwartz-Soicher created the data file which was used in the analyses. Julien Teitler and Andrew Gelman provided helpful suggestions.

Human Participant Protection

This study was approved by the institutional review boards of Robert Wood Johnson Medical School and Columbia University.

References

1. Akinbami LJ, Schoendorf KC. Trends in childhood asthma: prevalence, health care utilization, and mortality. *Pediatrics.* 2002;110:315–322.

2. Adams PF, Hendershot GE, Marano MA. Current estimates from the National Health Interview Survey, 1996. National Center for Health Statistics. *Vital Health Statistics.* 1999;10(200).

3. Litonjua AA, Carey VJ, Burge HA, et al. Parental history and the risk for childhood asthma: does mother confer more risk than father? *Am J Respir Crit Care Med.* 1998;158:176–181.

4. Duffy D, Martin N, Battistutta D, et al. Genetics of asthma and hay fever in Australian twins. *Am Rev Respir Dis.* 142(6 Pt 1):1351–8, 1990.

5. Sears MR. Epidemiology of childhood asthma. *Lancet.* 1997;350:1015–1020.

6. Newacheck PW, Halfon N. Prevalence, impact, and trends in childhood disability due to asthma. *Arch Pediatr Adolesc Med.* 2000;154:287–293.

7. Milton B, Whitehead M, Holland P, Hamilton V. The social and economic consequences of childhood asthma across the life course: a systematic review. *Child Care Health Dev.* 2004;30:711–728.

8. Maier WC, Arrighi HM, Morray B, Llewllyn C, Redding GJ. The impact of asthma and asthma-like illness in Seattle school children. *J Clin Epidemiol.* 1998;51:557–568.

9. Weiss KB, Gergen PJ, Crain EF. Inner-city asthma. The epidemiology of an emerging US public health concern. *Chest.* 1992;101(suppl 6):362S–367S.

10. Aligne AC, Auinger P, Byrd RS, Weitzman M. Risk factors for pediatric asthma: contributions of poverty, race, and urban residence. *Am J Respir Crit Care Med.* 2000;162:873–877.

11. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Menacker F, Munson ML. Births: Final data for 2002. Hyattsville, Maryland: Center for Disease Control and Prevention; 2003.

12. Reichman NE. Low birthweight and school readiness. *Future Child.* 2005;15:91–116.

13. Wjst M, Popescu M, Trepka MJ, Heinrich J, Wichmann HE. Pulmonary function in children with initial low birthweight. *Pediatr Allergy Immunol.* 1998; 9:80–90.

14. Shaheen SO, Sterne JAC, Montgomery SM, Azima H. Birth weight, body mass index and asthma in young adults. *Thorax.* 1999;54:396–402.

15. Brooks AM, Byrd RS, Weitzman M, Auinger P, McBride JT. Impact of low birthweight on early childhood asthma in the United States. *Arch Pediatr Adolesc Med.* 2001;155:401–406.

16. Dezateux C, Lum S, Hoo A-F, Hawdon J, Costeloe K, Stocks J. Low birthweight for gestation and airway function in infancy: Exploring the fetal origins hypothesis. *Thorax.* 2004;59:60–66.

17. Boezen HM, Vonk JM, van Aalderen WMC, Brand PLP, Gerritsen J, Schouten JP, et al. Perinatal predictors of respiratory symptoms and lung function at a young adult age. *Eur Respir J.* 2002;20:383–390.

18. Edwards CA, Osman LM, Godden DJ, Campbell DM, Douglas JG. Relationship between birthweight and adult lung function: Controlling for maternal factors. *Thorax.* 2003;58:1061–1065.

19. Schaubel D, Johansen H, Dutta M, Desmeules M, Becker A, Mao Y. Neonatal characteristics as risk factors for preschool asthma. *J Asthma.* 1996;33:255–64.

20. Seidman DS, Laor A, Gale R, Stevenson DK, Danon YL. Is low birthweight a risk factor for asthma during adolescence? *Arch Dis Child.* 1991;66:584–587.

21. Svanes C, Omenaas E, Heuch J, Irgens L, Gulsvik A. Birth characteristics and asthma symptoms in young adults: results from a population-based cohort study in Norway. *Eur Respir J.* 1998;12:1366–1370.

22. Hoo A-F, Stocks J, Lum S, Wade AM, Castle RA, Costeloe KL, et al. Development of lung function in early life: Influence of birthweight in infants of nonsmokers. *Am J Respir Crit Care Med.* 2004;170:527–533.

23. Rona RJ, Gulliford MC, Chinn S. Effects of prematurity and intrauterine growth on respiratory health and lung function in childhood. *BMJ.* 1993;306:817–820.

24. Joseph CLM, Ownby DR, Peterson EL, Johnson CC. Does low birthweight help to explain the increased prevalence of asthma among African-Americans? *Ann Allergy Asthma Immunol.* 88(May):507–512, 2002.

25. Dik N, Tate RB, Manfreda J, Anthonisen NR. Risk of physician-diagnosed asthma in the first 6 years of life. *Chest.* 2004;126:1147–1153.

26. Nafstad P, Magnus P, Jaakkola JJK. Risk of childhood asthma and allergic rhinitis in relation to pregnancy complications. *J Allergy and Clin Immunol.* 2000; 106:867–873.

27. Rasanen M, Kaprio J, Laitinen T, Winter T, Koskenvuo M, Laitinen LA. Perinatal risk factors for asthma in Finnish adolescent twins. *Thorax.* 2000;55: 25–31.

28. Wood D. Effect of child and family poverty on child health in the United States. *Pediatrics.* 2003; 112:707–711.

29. Miller JE. The effects of race/ethnicity and income on early childhood asthma prevalence and health care use. *Am J Public Health.* 2000;90:428–430.

30. Breysse PN, Galke W, Lanphear BP, Farr N. The relationship between housing and health: children at risk workshop. Columbia, MD: National Center for Healthy Housing; 2003.

31. Spencer N. Social, economic, and political determinants of child health. *Pediatrics.* 2003;112:704–706.

32. Montgomery LE, Kiely JL, Pappas G. The effects of poverty, race, and family structure on US children's health: data from the NHIS, 1978 through 1980 and 1989 through 1991. *Am J Public Health.* 1996;86:1401–1405.

33. Litonjua AA, Carey VJ, Weiss ST, Gold DR. Race, socioeconomic factors, and area of residence are associated with asthma prevalence. *Pediatr Pulmonol.* 1999; 28:394–401.

34. Sims M, Rainge Y. Urban poverty and infant-health disparities among African Americans and whites in Milwaukee. *J Natl Med Assoc.* 2002;94:472–479.

35. Reichman NE, Pagnini DL. Urban inequalities: birth outcomes across New Jersey cities. *Appl Behav Sci Rev.* 1998;6:111–136.

36. Reichman N, Teitler J, Garfinkel I, McLanahan S. Fragile Families: sample and design. *Child Youth Serv Rev.* 23(April/May):303–326, 2001.

37. Case A, Lubotsky D, Paxson C. Economic status and health in childhood: the origins of the gradient. *Am Econ Rev.* 2002;92:1308–1334.

38. Finch BK. Socioeconomic gradients and low birthweight: empirical and policy considerations. *Health Serv Res.* 2003; 38(6):1819–1841.

39. Currie J, Stabile M. Socioeconomic status and child health: Why is the relationship stronger for older children? *The Am Econ Rev.* 2003;93:1813–1823.

40. Halfon N, Newacheck PW. Childhood asthma and poverty: differential impacts and utilization of health services. *Pediatrics.* 1993;91:56–61.

41. Wissow LS, Gittelsohn AM, Szklo M, Starfield B, Mussman M. Poverty, race, and hospitalization for childhood asthma. *Am J Public Health.* 1988;78:777–782.

42. Bracken MB, Belanger K, Cookson WO, Triche E, Christiani DC, Leaderer BP. Genetic and perinatal risk factors for asthma onset and severity: a review and theoretical analysis. *Epidemiol Rev.* 2002;24:176–189.

43. Martinez F. Definition of pediatric asthma and associated risk factors. *Pediatr Pulmonol.* 1997;(suppl 15):9–12.

44. English DR, Hulse GK, Milne E, Holman CDJ, Bower CI. Maternal cannabis use and birthweight: a meta-analysis. *Addiction.* 1997;92:1553–1560.

45. Jaakkola JJK, Gissler M. Maternal smoking in pregnancy, fetal development, and childhood asthma. *Am J Public Health.* 2004;94:136–140.

46. Secker-Walker RH, Vacek PM. Relationships between cigarette smoking during pregnancy, gestational age, maternal weight gain, and infant birthweight. *Addict Behav.* 2003;28:55–66.

47. Ventura SJ, Hamilton BE, Mathews TJ, Chandra A. Trends and variations in smoking during pregnancy and low birthweight: evidence from the birth certificate, 1990–2000. *Pediatrics.* 2003;111:1176–1180.

48. Weitzman M, Gortmaker S, Walker DK, Sobol A. Maternal smoking and childhood asthma. *Pediatrics.* 1990;85:505–511.

49. Lanphear BP, Kahn RS, Berger O, Auinger P, Bortnick SM, Nahhas RW. Contribution of residential exposures to asthma in US children and adolescents. *Pediatrics.* 2001;107(6):E98–E105.

50. Rauh VA, Chew GL, Garfinkel RS. Deteriorated housing contributes to high cockroach allergen levels in inner-city households. *Environ Health Perspect.* 110 (suppl 2):161–171, 2002.

51. O'Campo P, Xue X, Wang M-C, Caughy MO. Neighborhood risk factors for low birthweight in Baltimore: a multilevel analysis. *Am J Public Health.* 1997; 87:1113–1118.

52. Roberts E. Neighborhood social environments and the distribution of low birthweight in Chicago. *Am J Public Health.* 1997;87:597–603.

53. Duran-Tauleria E, Rona RJ. Geographical and socioeconomic variation in the prevalence of asthma symptoms in English and Scottish children. *Thorax.* 1999;54:476–481.

54. Leaderer BP, Belanger K, Triche E, Holford T, Gold DR, Young K, et al. 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. *Environ Health Perspect.* 2002;110:419–425.

55. Katz KA, Pocock SJ, Strachan DP. Neonatal head circumference, neonatal weight, and risk of hayfever, asthma and eczema in a large cohort of adolescents from Sheffield, England. *Clin Exp Allergy.* 2003;33:737–745.

56. Gregory A, Doull I, Pearce N, Cheng S, Leadbitter P, Holgate S, et al. The relationship between anthropometric measurements at birth: asthma and atopy in childhood. *Clin Exp Allergy.* 1999;29:330–333.

57. Bolte G, Schmidt M, Maziak W, Keil U, Nasca P, von Mutius E, et al. The relation of markers of fetal growth with asthma, allergies and Serum Immunoglobulin E levels in children at age 5–7 years. *Clin Exp Allergy.* 2004;34:381–388.

58. Sin DD, Spier S, Svenson LW, Schopflocher DP, Senthilselvan A, Cowie RL, et al. The relationship between birthweight and childhood asthma: A population-based cohort study. *Arch Pediatr Adolesc Med.* 2004;158:60–64.

59. Leadbitter P, Pearce N, Cheng S, Sears MR, Holdaway DM, Flannery EM, et al. Relationship between fetal growth and the development of asthma and atopy in childhood. *Thorax.* 1999;54:905–910.

60. Grischkan J, Storfer-Isser A, Rosen CL, Larkin EK, Kirchner HL, South A, et al. Variation in childhood asthma among former preterm infants. *J Pediatr.* 2004; 144:321–326.

61. Darlow BA, Horwood JL, Mogridge N. Very low birthweight and asthma by age seven years in a national cohort. *Pediatr Pulmonol.* 2000;30:291–296.

62. Olivetti JF, Kercsmar CM, Redline S. Pre- and perinatal risk factors for asthma in inner city African-American children. *Am J Epidemiol.* 1996;143:570–577.

63. Kitchen WH, Olinsky A, Doyle LW. Respiratory health and lung function in 8-year old children of very low birthweight: A cohort study. *Pediatrics.* 1992; 89:1151–1158.

64. Hiscock R, Macintyre S, Kearns A, Ellaway A. Residents and residence: Factors predicting the health disadvantage of social renters compared to owner-occupiers. *J Social Issues.* 2003;59:527–546.

65. Macintyre S, Ellaway A, Der G, Ford G, Hunt K. Do housing tenure and car access predict health because they are simply markers of income or self esteem? A Scottish study. *J Epidemiol Community Health.* 1998;52:657–664.

66. Billings CG, Howard P. Damp housing and asthma. *Monaldi Arch Chest Dis.* 1998;53:43–49.

67. Williamson I, Martin C, McGill G, Monie R, Fennerty A. Damp housing and asthma: a case-control study. *Thorax.* 1997;52:229–234.

68. Yang CY, Chiu JF, Chiu HF, Kao WY. Damp housing conditions and respiratory symptoms in primary school children. *Pediatr Pulmonol.* 1997;24:73–77.

69. Andriessen JW, Brunekreef B, Roemer W. Home dampness and respiratory health status in European children. *Clin Exp Allergy.* 1998;28(10):1191–1200.

70. Gold DR, Burge HA, Carey V, Milton DK, Platts-Mills T, Weiss ST. Predictors of repeated wheeze in the first year of life. The relative roles of cockroach, birthweight, acute lower respiratory illness, and maternal smoking. *Am J Respir Crit Care Med.* 1999;160:227–236.

71. Etzel RA. How environmental exposures influence the development and exacerbation of asthma. *Pediatrics.* 2003;112:233–239.

72. Watson J, Cowen P, Lewis R. The relationship between asthma admission rates, routes of admission, and socioeconomic deprivation. *Eur Respir J.* 1996;9:2087–2093.

73. Cagney KA, Browning CR. Exploring neighborhood-level variation in asthma and other respiratory diseases. *J Gen Intern Med.* 2004;19:229–36.

74. Martinez FD. Recognizing early asthma. *Allergy.* 54(suppl 49):24–28, 1999.

75. Strunk RC. Defining asthma in the preschool-aged child. *Pediatrics.* 2002;109:357–361.

76. Martinez FD, Wright AL, Taussig LM, Holberg CJ, Halonen M, Morgan WJ, et al. Asthma and wheezing in the first six years of life. *N Engl J Med.* 1995;332: 133–138.