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Household Food Insecurity Is Associated with Childhood Asthma[1,2]

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Abstract

Background: In 2013, 20% of US households with children experienced food insecurity. Asthma afflicts over 7 million children; prevalence has steadily increased while incidence peaks in young children. Asthma and food insecurity share the determinants of poverty and race that are associated with weight, yet limited research on the relation between food insecurity and asthma exists.

Objective: The objective of this study was to determine the association between food insecurity and asthma in a diverse sample of children.

Methods: Cross-sectional data from grade 3 of the Early Childhood Longitudinal Study–Kindergarten Cohort were analyzed (n = 11,099). Food security based on the USDA module and asthma diagnosis were reported by parents; anthropometric factors were measured. Multivariate logistic regression models of food security and asthma were analyzed overall and by race/ethnicity.

Results: Children in food-insecure households had a 4% higher adjusted odds of asthma (95% CI: 1.02, 1.06). Adjusted odds of asthma were also higher by 70% for males (95% CI: 1.69, 1.71), 53% for non-Hispanic black (NHB) children (95% CI: 1.51, 1.54), 20% for Hispanic children (95% CI: 1.19, 1.21), 38% for overweight children (95% CI: 1.36, 1.39), 67% for obese children (95% CI: 1.65, 1.68), 23% for low–birth weight children (95% CI: 1.21, 1.24), 24% if mothers had a high school diploma (95% CI: 1.23, 1.26), and 33% if mothers had some college education (95% CI: 1.32, 1.35). High–birth weight children (OR: 0.84; 95% CI: 0.83, 0.85) and those with foreign-born mothers (OR: 0.52; 95% CI: 0.51, 0.53) had lower odds of asthma. Being food-insecure remained positively associated with asthma in non-Hispanic whites and Hispanics but was inversely associated with odds among NHBs. Odds of asthma doubled (OR: 2.00; 95% CI: 1.97, 2.03) for all children in households that were both food-insecure and poor; this relation remained positive in race/ethnicity-specific models.

Conclusions: Food insecurity is positively associated with asthma in US third graders, and household poverty strengthens the association. *J Nutr* 2015;145:2756–64.

Keywords: food insecurity, USDA Household Food Security Survey Module, asthma, Early Child Longitudinal Study–Kindergarten Cohort, BMI, birth weight, race

Introduction

In the United States in 2013, food insecurity, defined as "a limited or uncertain availability of nutritionally adequate or safe foods, or limited or uncertain ability to acquire food in socially acceptable ways," was reported in 14% of households and closer to 20% of households with children (1). These rates are troubling because food insecurity of any severity is associated with a host of physiologic, nutritional, and psychological problems in adults and children (2–8). Additionally, ethnic minorities, individuals in low-income households, individuals with limited education, and the uninsured are disproportionately affected by food insecurity (1, 9–13). Although the prevalence of food insecurity is higher in households with incomes below the federal poverty line, food insecurity poses a risk to health independent of that related to low socioeconomic status (SES)[5] (1, 14–16).

Another major health concern for school-aged children in the United States is asthma, the most common chronic childhood disease (17, 18). The prevalence of asthma has been increasing in

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[5] Abbreviations used: ECLS-K, Early Childhood Longitudinal Study–Kindergarten Cohort; HFSSM, Household Food Security Survey Module; LBW, low birth weight; NHB, non-Hispanic black; NHW, non-Hispanic white; SES, socioeconomic status.

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the last 3 decades, with rates higher in children than in adults. In an analysis of the US population from the National Health Interview Survey, 12 mo period prevalence nearly doubled from 1980–1996, and asthma prevalence increased from 7.3% to 8.2% between 2001 and 2009. In the period 2006–2008, asthma incidence was higher in children than in adults, with the highest incidence rate (23.4 cases per 1000 at risk) in those 0–4 y old compared with children 5–11 y old (11.1 of 1000) and children aged 12–17 y (4.4 of 1000) (19). Similar to food insecurity, there are disparities in the prevalence of asthma. Hispanics of Puerto Rican descent have the highest rate of diagnosis, followed by non-Hispanic blacks (NHBs), then non-Hispanic whites (NHWs), with Hispanics of Mexican descent experiencing the lowest prevalence (17, 20–23). Other risk factors for childhood asthma are male sex, obesity, and living below the federal poverty level (17, 18).

The pathophysiology of asthma appears to be a complex interaction between genetic predisposition or characteristics [e.g., maternal asthma, ethnicity, low birth weight (LBW), or high childhood BMI], prenatal factors (e.g., maternal smoking), and social and physical environmental exposures (e.g., poverty, stressful life events, or secondhand cigarette smoke exposure), depending in part on timing relative to developmental stages of the life course (24–28). Yet, relatively few studies have looked at exposures related to nutritional status, such as food insecurity, as contributors to asthma. In a 2013 Brazilian study, the odds of asthma, as indicated by reports of wheezing, was associated with moderate or severe food insecurity (measured by the Brazilian Food Insecurity Scale) in a dose-response relation in 1307 children aged 6–12 y attending public elementary schools (29). In youth aged 16–21 y followed as part of the Canadian National Longitudinal Study of Children and Youth, experiencing ≥2 episodes of hunger from food shortage (measured by a single item) resulted in more than double the odds of asthma (OR: 2.38; 95% CI: 1.14, 4.94) (30). To our knowledge, no study has assessed the relation between household food insecurity, as measured by the validated USDA Household Food Security Survey Module (HFSSM), and asthma in US children.

The Early Childhood Longitudinal Study–Kindergarten Cohort (ECLS-K) is composed of ethnically diverse school-aged children in the United States who were recruited in kindergarten during the fall of 1998. In its third grade wave, parents were asked whether their child had ever been diagnosed with asthma by a health care professional. Household food security for the preceding 12 mo was assessed with the use of the full 18-item HFSSM (31–33). The objectives of this analysis were to estimate the prevalence of asthma and determine the association between food insecurity and odds of asthma in ECLS-K children in grade 3 before and after taking into account maternal and child sociodemographic factors.

Methods

Subjects

The ECLS-K was a nationally representative sample of kindergarteners in schools across the United States in 1998–1999 that used a dual-frame, multistage probability cluster design (34). There were 7 waves of data collection between 1998 and 2007, starting in the fall of kindergarten (1998) and going through the spring of grade 8. Minority ethnic groups were oversampled in the fall of kindergarten; specifically, 55.1% were NHW, 15.3% NHB, 17.9% Hispanic, 7.5% Asian/Pacific Islander, 1.8% Native American, and 2.4% other (mixed or unknown) (n = 21,042) (34). Children enrolled in kindergarten were representative of all US kindergarteners in that year; data from subsequent years were representative of the ECLS-K cohort only (31, 34). Using the nonrestricted, public-use data set, we focused on parent-reported data from the spring of grade 3 (2002) (35). The sample was freshened in the spring of grade 1 with children who had not attended kindergarten in 1998–1999. The grade 3 sample included baseline kindergarten respondents, the freshened grade 1 sample, and a random 50% subsample of children who were followed after moving from their kindergarten schools (34).

Of all respondents in the spring of grade 3, children with missing or incomplete data on sex, race/ethnic group, household food security or poverty status, asthma, weight, birth weight, health insurance coverage, and maternal nativity or education were excluded from the analytic sample (n = 4206). Exclusion criteria covered duplicate data in the form of twin siblings; thus, only one child per household was randomly selected for inclusion in the sample. The final unweighted analytic sample size was 11,099. In the majority of cases, the biological mother was the telephone interview respondent (91% of NHWs, 83% of NHBs, and 88% of Hispanics). Other respondents included the biological father, an "other mother" type, or a nonparent relative (<10% of all cases for each race/ethnic group).

Measures

Food security. Household food security was measured with the use of the USDA 18-item HFSSM, which is designed to capture the severity of food insecurity in a household and its members' experiences with and responses to limited access or availability of adequate or acceptable food over the 12 mo before the questionnaire administration (32, 36). The full module was embedded in the telephone interview administered to parents in the spring of 2002; thus, the reference period was the 12 mo before the spring of the child's grade 3 school year. The parent responded with "yes" or "no" to the questions or statements in the module, 10 of which refer to adult members of the household, and 8 to the index child (31). The standard coding protocol classifies those households with ≤2 affirmative responses as food-secure, and households with ≥3 positive responses as food-insecure to some degree (32). The composite categorical variable in the data set has 4 values, corresponding to divisions of the Rasch transformation of raw scores on the module: food-secure, food insecure without hunger, food insecure with moderate hunger, and food insecure with severe hunger (31). In 2006, the terminology changed: "low food security" replaced the "food insecure without hunger" category, and the 2 food-insecure with hunger categories were subsumed into "very low food security" (37). For these analyses, food security status was treated as either a dichotomous or trichotomous variable. For the former, households were categorized as food-secure or food-insecure (all responses other than food secure). The trichotomous variable had food-secure (0 affirmative responses to the HFSSM), marginally food-secure (1 or 2 affirmative responses), or food-insecure (≥3 affirmative responses).

Asthma. Asthma in the child was assessed in the grade 3 parent interview with a single dichotomous yes or no item: "Has a doctor, nurse, or other medical professional ever told you that your child has asthma?" A similar item is used in the National Health Interview Survey and a module in the Behavioral Risk Factor Surveillance System to assess diagnosis of asthma by a health professional (19).

Covariates. Sociodemographic and anthropometric variables from the parent questionnaire and direct child measurement, respectively, were included in the analysis as covariates. Specifically, the following were used: race/ethnicity; household poverty status in relation to census thresholds; child sex; maternal nativity and education; child health insurance; height, weight, and birth weight; and household income.

Race/ethnicity was reported by the parent and from the baseline enrollment data if parent report was missing in grade 3 (31). The 7 composite categories of race/ethnicity were condensed to 4 groups: NHWs, NHBs, Hispanics (of any race), and Asian/other. The latter category included Asian, Native Hawaiian/Pacific Islander, American Indian/Alaska Native, or more than one race (all non-Hispanic) (n = 1282).

Household poverty included a dichotomous variable, calculated from a comparison of the reported income range of the household

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based on 2001 census poverty thresholds, which took into account household size. Households were classified as at/above or below the poverty threshold (31).

Maternal nativity was constructed with the use of the mother's country of birth reported in grades 1, 3, and 5. Multiple waves of data were used to limit exclusion from missing data. Nativity was classified as "US-born" if data on the United States as the country of birth was concordant across the first, third, and fifth grade waves. Maternal nativity was "foreign-born" if any country of origin other than the United States was reported at any wave.

Maternal education, a marker of SES, classified mothers as having less than a high-school diploma, a high-school diploma or a vocational/technical degree, or any college or higher based on parent report in grade 3 (38). The latter category included those with any college or university as well as a bachelor's or any advanced degree.

Child health insurance was based on one item response from the parent questionnaire from the spring of grade 3 that asked whether the child currently did not have health insurance. A child was classified as being uninsured if the response was affirmative, and otherwise insured.

Children's heights and weights were assessed directly by ECLS-K field staff in grade 3. Height was measured by ShorrBoard and weight with a digital bathroom scale; each child's measurements were taken 2 times and the average of these 2 measurements was used in analysis (31, 39). Any child with a difference of >2 inches (5.08 cm) between the 2 height measurements was excluded from analyses (n = 31). If the measurements differed by <2 inches, the average of the 2 measurements was used for the height of the child. For weight, any child with a difference of >5 pounds (2.27 kg) between measurements was excluded from analyses (n = 41). If the measurements differed by <5 pounds, the average of the 2 measurements was used for weight of the child (40). If children had one missing weight but another value within a reasonable range for age was recorded, the single measurement was included in analyses (n = 3). A continuous BMI percentile was calculated with the use of the CDC age- and sex-specific referent data; the percentiles were classified into lean/normal (<85th percentile), overweight (85th–94th percentile) or obese (≥95th percentile) (41).

Children's birth weights were based on parent-reported data from either the spring of kindergarten or the grade 1 year. Birthweights reported in pounds and ounces were converted to grams; if a value in pounds was present but ounces were missing, a value of 8 ounces was the default. Birth weight was calculated in gram amounts to classify each child as LBW (<2500 g), normal birth weight (2500–3999 g), or high birth weight (≥4000 g).

Household income was based on parent-reported data from the spring of grade 3 questionnaire. The 13 categories of income were merged into 3 groups: households making ≤$15,000/y; households making $15,001–$50,000/y; and households making ≥$50,001/y.

Analyses

Descriptive statistics (mean, median, and mode for continuous variables and frequencies for categorical ones) were generated for food insecurity, asthma, and sociodemographic and anthropometric variables in the

TABLE 1 Characteristics of the ECLS-K grade 3 year (2002), overall and by race/ethnicity[1]

	All	NHW	NHB	Hispanic
Total	**11,099**	**6837 (62)**	**1201 (11)**	**1865 (17)**
Food security				
Food secure	10,339 (93)	6548 (96)	1048 (87)	1645 (88)
Food insecure	760 (7)	289 (4)	153 (13)	220 (12)
Asthma				
Yes	1334 (12)	745 (11)	227 (19)	223 (12)
No	9765 (88)	6092 (89)	974 (81)	1642 (88)
Poverty				
Below threshold	1987 (18)	561 (8)	498 (42)	647 (35)
At/above threshold	9112 (82)	6276 (92)	703 (59)	1218 (65)
Sex				
M	5660 (51)	3493 (51)	607 (51)	957 (51)
F	5439 (49)	3344 (49)	594 (50)	908 (49)
Maternal nativity				
US-born	8984 (81)	6526 (96)	1115 (93)	795 (43)
Foreign-born	2115 (19)	311 (5)	86 (7)	1070 (57)
Maternal education				
Less than high school	1148 (10)	283 (4)	169 (14)	561 (30)
High school diploma or vocational/technical school degree	3321 (30)	1923 (28)	448 (37)	607 (33)
Any college or higher	6630 (59)	4631 (68)	584 (49)	697 (37)
Maternal age, y	38 ± 6.3	38.6 ± 5.8	36.5 ± 8.1	36.4 ± 6.4
Health insurance				
Child insured	9242 (83)	5794 (85)	953 (79)	1462 (78)
Child uninsured	1857 (17)	1043 (15)	248 (21)	403 (22)
BMI percentile				
<85 (lean/normal)	7253 (65)	4687 (69)	720 (60)	1080 (58)
85–94.99 (overweight)	1749 (16)	1040 (15)	204 (17)	314 (17)
≥95 (obese)	2097 (19)	1110 (16)	277 (23)	471 (25)
Birth weight, g				
<2500 (low)	769 (7)	371 (5)	163 (14)	138 (7)
2500–3999 (normal)	9011 (81)	5503 (81)	965 (80)	1535 (82)
≥4000 (high)	1319 (12)	963 (14)	73 (6)	192 (10)

[1] Values are unweighted n (%) or means ± SDs; percentages may not sum to 100 because of rounding. ECLS-K, Early Childhood Longitudinal Study–Kindergarten Cohort; NHB, non-Hispanic black; NHW, non-Hispanic white.

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entire unweighted sample. Pearson's χ^2 tests and 1-factor ANOVA were computed to compare children in food-secure compared with food-insecure households with the use of the unweighted data. Multiple logistic regression models with the use of the ECLS-K cross-sectional sample weights for the data were created to generate ORs with 95% CIs for a diagnosis of asthma by food security with and without adjustment for covariates (34). In adjusted logit models, food security was treated 3 different ways as described above, notably, dichotomous, trichotomous, and then a dichotomous treatment with the marginal food-secure households combined with the food-insecure ones. The logit models were computed for the entire sample and then stratified by 3 race/ethnic groups: NHW, NHB, or Hispanic (of any race). The Asian/other group was included in the overall logistic regression model only, because it was deemed too heterogeneous for an analysis stratified by race/ethnic group. To retain power, sex was entered as a covariate in all models rather than in stratified analysis/models. Additional weighted logit models were created to include the 4-level interaction term for food insecurity by household poverty for the overall sample and by race/ethnicity, adjusting for significant covariates. Supplemental analyses included a weighted, adjusted logistic regression model with household income substituted for poverty status. Analyses were done with SPSS 21.0 for Windows or for weighted analysis with SAS 9.2 for Windows. Significance was set at $P < 0.05$ for all analyses.

Results

The prevalence of food insecurity in the previous 12 mo and ever diagnosed with asthma, sociodemographic and maternal characteristics, and anthropometric measures in the entire sample and by race/ethnic group appear in **Table 1**. Seven percent of the entire sample lived in a food-insecure household, with the range in prevalence from 4% in NHWs to 12% in Hispanics and 13% in NHBs. The prevalence of asthma in the total sample was 12% and ranged from 11% in NHW to 12% in Hispanics and 19% in NHBs. The sample included 18% who lived in households below the poverty threshold with ethnic group differences ranging as low as 8% of NHW to 42% NHB. Fifty-one percent of the sample was male. Foreign-born mothers accounted for 19% of the overall sample, with foreign-born maternal nativity rates higher in Hispanics (57%) than in NHWs and NHBs (5% and 7%, respectively). Mothers with less than a high school education comprised 10% of the total but this group ranged from 30% of Hispanics to 14% of NHBs and 4% of NHWs (Table 1). Besides race/ethnicity, asthma prevalence differed by food security, household poverty status, and child's BMI and birth weight. In NHWs, NHBs, and Hispanics, asthma prevalence was higher in children living in food-insecure households. In NHWs and NHBs, asthma prevalence was higher in those living below poverty. In NHWs and Hispanics, but not NHBs, asthma prevalence was higher in overweight and obese children than in normal-weight children, and higher in LBW children than in normal- and high–birth weight children (**Figure 1**). Compared with children in food-secure households, children in food-insecure households were more likely to be living below the poverty level, be non-NHW, have mothers born outside of the United States or of low educational level, be uninsured, and be currently obese or born LBW (**Table 2**).

In the adjusted logistic regression model for the entire sample (**Table 3**), the following was associated with a higher odds of asthma: living in poverty (OR: 1.26; 95% CI: 1.25, 1.28), a food-insecure household (OR: 1.04; 95% CI: 1.02, 1.06), or a food-insecure and poor household (OR: 2.00; 95% CI: 1.97, 2.03); being NHB (OR: 1.53; 95% CI: 1.51, 1.54) or Hispanic (OR: 1.20; 95% CI: 1.19, 1.21); being male (OR: 1.70; 95% CI: 1.69, 1.71); maternal education at the level of high-school diploma or vocational/technical school (OR: 1.24; 95% CI: 1.23, 1.26) or any college or above (OR: 1.33; 95% CI: 1.32, 1.35); child being overweight (OR: 1.38; 95% CI: 1.36, 1.39) or obese (OR: 1.67; 95% CI: 1.65, 1.68); child being insured

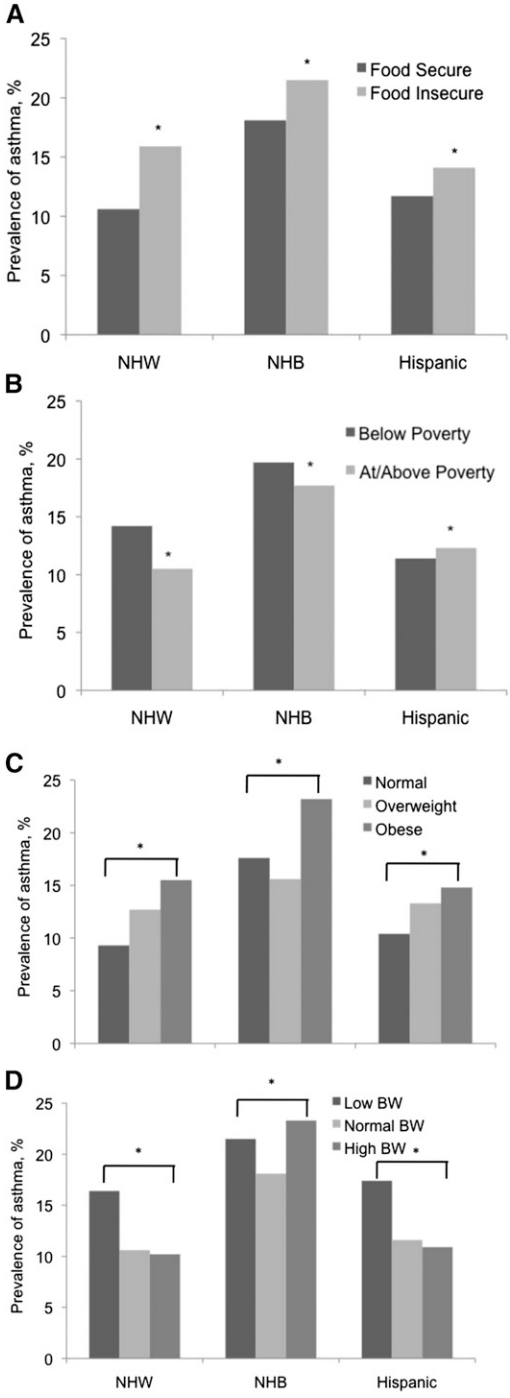

FIGURE 1 Prevalence of asthma in third-graders in the ECLS-K by race/ethnicity and household food security (A), household poverty (B), child BMI (C), and birth weight (D). Pearson's chi-square tests were computed with weighted data to test differences in prevalence of asthma between levels of the variables in Panels A–D within race/ethnic groups (NHW, NHB, and Hispanic). *Within race/ethnic group, different from corresponding value, $P < 0.001$. The unweighted sample size for panels A–C was $n = 6961$ (NHW), $n = 1284$ (NHB), and $n = 1953$ (Hispanic); for panel D, the sample size was $n = 6837$ (NHW), $n = 1201$ (NHB), and $n = 1865$ (Hispanic). BW, birth weight; ECLS-K, Early Childhood Longitudinal Study–Kindergarten Cohort; NHB, non-Hispanic black; NHW, non-Hispanic white.

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TABLE 2 Distribution of ECLS-K third-graders by household food security status[1]

	Food-secure	Food-insecure	*P*
Total	10,339 (93)	760 (7)	
Poverty			<0.001
Below threshold	1555 (15)	432 (57)	
At/above threshold	8784 (85)	328 (43)	
Race/ethnicity			<0.001
NHW	6548 (63)	289 (38)	
NHB	1048 (10)	153 (20)	
Hispanic	1645 (16)	220 (29)	
Sex			<0.001
M	5273 (51)	387 (51)	
F	5066 (49)	373 (49)	
Maternal nativity			<0.001
US-born	8449 (82)	535 (70)	
Foreign-born	1890 (18)	225 (30)	
Maternal education			<0.001
Less than high school	932 (9)	216 (28)	
High school diploma or vocational/technical school degree	3026 (29)	295 (39)	
Any college or higher	6381 (62)	249 (33)	
Maternal age, y	38 ± 6.3	36 ± 6.9	<0.001
Health insurance			<0.001
Child insured	8637 (84)	605 (80)	
Child uninsured	1702 (17)	155 (20)	
BMI percentile			<0.001
<85 (lean/normal)	6801 (66)	452 (60)	
85–94.99 (overweight)	1623 (16)	126 (17)	
≥95 (obese)	1915 (19)	182 (24)	
Birth weight, g			<0.001
<2500 (low)	680 (7)	89 (12)	
2500–3999 (normal)	8418 (81)	593 (78)	
≥4000 (high)	1241 (12)	78 (10)	

[1] Values are unweighted *n* (%) or means ± SDs; percentages may not sum to 100 because of rounding. Food security was defined by ≤2 affirmative responses to the Household Food Security Survey Module. *P* values are based on Pearson's chi-square tests for categorical variables and 1-factor ANOVA for continuous variables with the use of weighted data. ECLS-K, Early Childhood Longitudinal Study–Kindergarten Cohort; NHB, non-Hispanic black; NHW, non-Hispanic white.

(OR: 1.23; 95% CI: 1.21, 1.24); and LBW of the child (OR: 1.23; 95% CI: 1.21, 1.24). In contrast, a reduction in odds of asthma was seen with maternal nativity outside the United States (OR: 0.52; 95% CI: 0.51, 0.53) and child high birth weight (OR: 0.84; 95% CI: 0.83, 0.85). Treating food security as a trichotomous variable in weighted, adjusted models without food security × poverty interaction terms did not alter the direction or strengths of these associations; notably, marginal food insecurity was associated with 34% higher odds of asthma (95% CI: 1.33, 1.36). Similarly, when marginally food-insecure households were grouped with food-insecure households, the OR for asthma was 1.36 (95% CI: 1.35, 1.37) (data not shown).

In Hispanics (in ethnic group–specific logistic models; Table 3), a 35% higher odds of asthma was associated with food insecurity, whereas poverty increased asthma by 34% (95% CI: 1.29, 1.41); and the odds more than doubled for Hispanics in food-insecure and poor households (OR: 2.32; 95% CI: 2.25, 2.38). In NHBs, food insecurity was negatively associated with asthma (OR: 0.56; 95% CI: 0.53, 0.58), whereas food insecurity and poverty together were positively associated with asthma (OR: 1.77; 95% CI: 1.73, 1.82). In NHWs, food insecurity was positively associated with asthma (OR: 1.21; 95% CI: 1.18, 1.24), as was the combination of food insecurity and poverty (OR: 1.80; 95% CI: 1.76, 1.85). Male sex, any level of maternal education of high school degree or higher, child obesity, and LBW increased the odds of asthma for NHW, NHB, and Hispanic children, whereas maternal nativity outside the United States remained associated with reduced odds of asthma across all race/ethnicity groups (Table 3). Overweight increased the odds of asthma in NHWs by 59% (95% CI: 1.57, 1.61) and in Hispanics by 37% (95% CI: 1.33, 1.40), but the relation was inverted in NHBs (OR: 0.97; 95% CI: 0.95, 0.99). Being insured was associated with increased odds of asthma by 37% (95% CI: 1.34, 1.39) in NHWs and by 19% (95% CI: 1.16, 1.21) in NHBs, but with decreased odds by 4% (95% CI: 0.94, 0.98) in Hispanics. High birth weight was associated with increased odds of asthma in NHBs (OR: 1.34; 95% CI: 1.31, 1.38), but decreased odds of asthma in NHWs (OR: 0.79; 95% CI: 0.78, 0.80) and Hispanics (OR: 0.69; 95% CI: 0.67, 0.71) (Table 3). Using a trichotomous classification of food security or grouping marginally food-secure households with food-insecure households in the stratified models did not change the findings (data not shown). When poverty status was replaced by household income in a supplemental logit model without a food insecurity × income interaction term, compared with the referent household income of ≥$50,001/yr, an increased odds of asthma was associated with an income of ≤$15,000/yr (OR: 1.47; 95% CI: 1.46, 1.49) and an income of $15,001–$50,000/y (OR: 1.02; 95% CI: 1.01, 1.03). Other associations with asthma were of identical direction and similar significance as those in Table 3 (data not shown).

Discussion

In grade 3 children of the ECLS-K cohort, the overall unweighted prevalence of food insecurity (7%) and asthma (12%) were comparable to national rates in 2002, the same year of the study (42, 43). Rates of both conditions were higher in race/ethnic minorities in the ECLS-K, with rates of asthma diagnosis highest in NHBs and boys of all ethnic groups, mirroring national trends (1, 17). The key findings were the positive associations between food insecurity alone and the interaction of food insecurity with poverty and the odds of asthma after adjustment for covariates in the overall sample. In ethnic group-specific models, the relation between food insecurity and asthma remained and was stronger in Hispanics than in NHWs, but was reversed in NHB children. The positive association between food insecurity and asthma was stronger in those living in poor households than in households at or above the poverty line, and this interaction was strongest in Hispanics compared with NHWs and NHBs.

To our knowledge, for the first time, we demonstrate that household food insecurity is associated with higher odds of asthma in school-aged children. Moreover, these results were examined in a large, diverse cohort of US children with the use of the validated HFSSM (44). In a Brazilian study of 1307 children aged 6–12 attending public elementary schools, odds of asthma were positively associated with food insecurity in a dose-response manner independent of age, sex, weight, and tobacco exposure (29). The ethnic group differences seen here in the magnitude and direction of the association between food insecurity and asthma can be understood within the framework of a life course model of health disparities, in which biosocial factors interact to shape health and disease outcomes within individual lifetimes and across generations (45). Exposure to poverty

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TABLE 3 Adjusted ORs (95% CIs) of asthma diagnosis for all third-graders and by race/ethnicity in the ECLS-K[1]

	n	All	NHW	NHB	Hispanic
Household status					
Food-secure, not poor	9003	Reference	Reference	Reference	Reference
Food-secure, poor	1673	1.26 (1.25, 1.28)**	1.45 (1.43, 1.47)**	1.16 (1.14, 1.18)**	1.34 (1.31, 1.37)**
Food-insecure, not poor	338	1.04 (1.02, 1.06)**	1.21 (1.18, 1.24)**	0.56 (0.53, 0.58)**	1.35 (1.29, 1.41)**
Food-insecure, poor	466	2.00 (1.97, 2.03)**	1.80 (1.76, 1.85)**	1.77 (1.73, 1.82)**	2.32 (2.25, 2.38)**
Race/ethnicity					
NHW	6961	Reference			
NHB	1284	1.53 (1.51, 1.54)**			
Hispanic	1953	1.20 (1.19, 1.21)**			
Sex					
F	5620	Reference	Reference	Reference	Reference
M	5860	1.70 (1.69, 1.71)**	1.74 (1.73, 1.76)**	1.73 (1.70, 1.75)**	1.75 (1.72, 1.78)**
Maternal nativity					
US-born	9221	Reference	Reference	Reference	Reference
Foreign-born	2259	0.52 (0.51, 0.53)**	0.80 (0.79, 0.82)**	0.48 (0.46, 0.50)**	0.46 (0.45, 0.47)**
Mother's education					
Less than high school	1247	Reference	Reference	Reference	Reference
High school diploma or vocational/technical school degree	3448	1.24 (1.23, 1.26)**	1.10 (1.08, 1.12)**	1.29 (1.26, 1.33)**	1.15 (1.12, 1.17)**
Any college or higher	6785	1.33 (1.32, 1.35)**	1.18 (1.16, 1.20)**	1.21 (1.18, 1.24)**	1.61 (1.57, 1.64)**
BMI					
Normal	7502	Reference	Reference	Reference	Reference
Overweight	1813	1.38 (1.36, 1.39)**	1.59 (1.57, 1.61)**	0.97 (0.95, 0.99)*	1.37 (1.33, 1.40)**
Obese	2165	1.67 (1.65, 1.68)**	1.86 (1.84, 1.88)**	1.46 (1.43, 1.49)**	1.46 (1.44, 1.49)**
Health Insurance					
No	1921	Reference	Reference	Reference	Reference
Yes	9559	1.23 (1.21, 1.24)**	1.37 (1.34, 1.39)**	1.19 (1.16, 1.21)**	0.96 (0.94, 0.98)**
Birthweight					
Low (<2500 g)	769	1.23 (1.21, 1.24)**	1.37 (1.34, 1.39)**	1.17 (1.15, 1.20)**	1.08 (1.05, 1.12)**
Normal (2500–3999 g)	9011	Reference	Reference	Reference	Reference
High (≥4000 g)	1319	0.84 (0.83, 0.85)**	0.79 (0.78, 0.80)**	1.34 (1.31, 1.38)**	0.69 (0.67, 0.71)**

[1] For each category, *n* is for the entire unweighted sample. All logistic models were done with the use of cross-sectional sample weights. Adjusted model included food security status, poverty status, food security × poverty interaction, race/ethnicity, sex, maternal nativity and education, child insurance coverage, and BMI and birth weight category. *$P <$ 0.01 and **$P < 0.001$. ECLS-K, Early Childhood Longitudinal Study–Kindergarten Cohort; NHB, non-Hispanic black; NHW, non-Hispanic white.

emerged as a significant contributor to earlier age at menarche in NHWs, but not in NHBs, in a nationally representative birth cohort. Likewise, food insecurity may be a marker for socio-environmental exposures to stress in some, but not all, race/ethnic groups (46).

Just as compelling is the finding that food insecurity is more strongly associated with the odds of asthma in those children living in households below the poverty level. Poverty is associated with both adverse health in children and food insecurity, and has lasting effects even when SES improves later in life (47, 48). Studies have shown that exposure to hunger is associated with an ever-diagnosis of asthma in adolescent youth (30, 49). The combination of poverty and food insecurity may increase the risk of hunger and insufficient nutrition for children and adults in a household. Although development of asthma is complex, it may involve parental reactions to stress related to poor nutrition and lack of resources, as is seen in poverty and food insecurity, and these processes may vary across race/ethnic groups (49, 50).

Overweight and obesity were associated with higher odds of asthma in the overall and ethnic-stratified sample, with the exception of lower odds of asthma being associated with overweight in NHBs. The overall patterns of these findings are in line with evidence from a recent meta-analysis; the association between obesity and asthma symptoms may be mutually reinforcing (51, 52). Further research is warranted on mechanisms that underlie the relation between weight and asthma; care should be taken to apply methods that will disentangle cause and effect relations and identify possible mediating factors, especially in minority children.

The finding that children of mothers born outside of the United States had a lower odds of asthma than offspring of US-born mothers is largely consistent with previous observations (53–55). Maternal nativity could be a marker for exclusive breastfeeding of an infant or lower levels of exposure to environmental tobacco smoke, both of which are protective against asthma (55–57).

The positive associations between levels of maternal education past high school and having health insurance with odds of asthma are counterintuitive. Higher education usually goes hand-in-hand with higher income and access to resources, whereas the uninsured typically have worse health and more hospitalizations (47, 58). However, mothers with more education may be more aware of signs of asthma in a child, prompting a doctor visit for a diagnosis, and better able to navigate health-care infrastructure. Access to clinical care from being insured may be driving a detection bias for asthma. The slight decrease in odds of asthma for insured Hispanic children could reflect lack of health care use by different subgroups of Hispanics (59).

LBW is an established risk factor for childhood asthma, and was associated with elevated odds of asthma in all analyses (26, 60). High birth weight was protective against asthma in

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NHWs and Hispanics, but associated with raised odds of asthma in NHBs. Historically, NHBs have the highest rates of LBW in the United States (61). Maternal prepregnancy obesity has also been linked to a diagnosis of asthma in offspring (62). Heavier NHB mothers may bear heavier children, and if the birth-weight distribution shifts to the left, any advantages that higher birth weight might confer upon non-NHB children may not extend to NHBs at the higher end of the distribution.

This study has both limitations and strengths. There is always potential for misclassification of child health status with parent-reported data. Certain prenatal and environmental exposures that have previously been associated with the odds of asthma were not collected in this study (28, 62–64). For example, cigarette smoking is associated with both food insecurity and asthma, but data on exposure to parental smoke were not collected (63, 65). Cross-sectional analyses reveal associations, but do not assess causality. Findings from studies of food insecurity and health outcomes suggest that household food insecurity may contribute to disease onset; however, it is possible that asthma or another disease preceded exposure to food insecurity (18, 44, 66, 67). Furthermore, reported food insecurity for the 12 mo before the spring of grade 3 inevitably raises the questions of the effects of lifetime frequency and severity of food insecurity on chronic disease risk. In a longitudinal analysis of the ECLS-K cohort, one-third of households experienced food insecurity at some point, and risk was heightened in ethnic minorities and low-income households (68). Despite the fact that persistent food insecurity is relatively uncommon, it is unclear how the length of an exposure may tip the scale in terms of vulnerability to asthma (44, 69). Residual confounding in analyses from variables such as smoking or SES associated with food insecurity and asthma is another considerable limitation. Additionally, exclusion of cases because of missing data may have contributed to selection bias in results.

Strengths of this analysis include internal and external construct validity in the sample. The internal validity of the data were checked with the use of parent-reported birth weight against the offspring's prematurity (70). External validity of the birth weight and anthropometric data were confirmed with the use of national data (40, 71, 72). Higher rates of poverty in children living in food-insecure households compared with those in food-secure households is expected, given national trends, and is evident in this sample (1). Ethnic diversity, assessment of childhood asthma diagnosis, and use of the HFSSM are advantages of the ECLS-K that make it well suited to study the association between food insecurity and asthma in children. The large sample size also enabled the exclusion of cases with missing/incomplete information, with little reduction of power and no change in the percentages of children classified as food-insecure, asthmatic, or living under the poverty level.

The novel findings of this analysis are that food insecurity is positively associated with odds of asthma in ECLS-K third-graders, and the strength of association is increased in children living in poverty. In 2012, 22% of US children lived in poverty, and similar percentages were exposed to food insecurity at the household level (47, 73). Both poverty and food insecurity are associated with deleterious outcomes for children, are urgent public health priorities, and affect non-NHW minorities in higher numbers (47). As this research underscores, the approach to food insecurity must be a comprehensive one, accounting for other household and sociodemographic factors, and may work best in conjunction with poverty alleviation measures tailored to specific race/ethnic groups and focused on covariates such as maternal nativity.

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LDM, MDH, and MRF designed the research; LDM and YQD analyzed the data; LDM and MRF wrote the paper; and LDM had primary responsibility for the final content. All authors read and approved the final manuscript.

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