

Food Allergy and Increased Asthma Morbidity in a School-Based Inner-City Asthma Study

James L. Friedlander, MD^a, William J. Sheehan, MD^a, Sachin N. Baxi, MD^a, Lianne S. Kopel, MD^b, Jonathan M. Gaffin, MD, MMSc^b, Al Ozonoff, PhD^{c,d}, Chunxia Fu, MS^e, Diane R. Gold, MD, MPH^e, and Wanda Phipatanakul, MD, MS^{a,e} *Boston, Mass*

What is already known about this topic? Food allergy prevalence is increased in people with asthma. The relationship between food allergy and asthma morbidity is not well described.

What does this article add to our knowledge? The presence of food allergy and multiple food allergies is associated with increased asthma morbidity, resource utilization, and decreased lung function.

How does this study impact current management guidelines? Impoverished, urban, nonwhite children with both food allergies and asthma may require greater asthma surveillance than those with asthma alone.

BACKGROUND: Children with asthma have increased prevalence of food allergies. The relationship between food allergy and asthma morbidity is unclear.

OBJECTIVE: We aimed to investigate the presence of food allergy as an independent risk factor for increased asthma morbidity by using the School Inner-City Asthma Study,

a prospective study that evaluates risk factors and asthma morbidity among urban children.

METHODS: We prospectively surveyed, from inner-city schools, 300 children with physician-diagnosed asthma, followed by clinical evaluation. Food allergies were reported, which included symptoms experienced within 1 hour of food ingestion. Asthma morbidity, pulmonary function, and resource utilization were compared between children with food allergies and those without.

RESULTS: Seventy-three of 300 children with asthma (24%) surveyed had physician-diagnosed food allergy, and 36 (12%) had multiple food allergies. Those with any food allergy independently had increased risk of hospitalization (OR [odds ratio] 2.35 [95% CI, 1.30-4.24]; $P = .005$) and use of controller medication (OR 1.99 [95% CI, 1.06-3.74]; $P = .03$). Those with multiple food allergies also had an independently higher risk of hospitalization in the past year (OR 4.10 [95% CI, 1.47-11.45]; $P = .007$), asthma-related hospitalization (OR 3.52 [95% CI, 1.12-11.03]; $P = .03$), controller medication use (OR 2.38 [95% CI, 1.00-5.66]; $P = .05$), and more provider visits (median, 4.5 vs 3.0; $P = .008$). Furthermore, lung function was significantly lower (percent predicted FEV₁ and FEV₁/FVC ratios) in both food allergy category groups.

CONCLUSIONS: Food allergy is highly prevalent in inner-city school-aged children with asthma. Children with food allergies have increased asthma morbidity and health resource utilization with decreased lung function, and this association is stronger in those with multiple food allergies. © 2013 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol: In Practice 2013;1:479-84)

Key words: Asthma; Food allergy; Hospitalization; Morbidity; Prevalence; Resource utilization; Risk

^aDivision of Immunology, Boston Children's Hospital, Harvard Medical School, Boston, Mass

^bDivision of Respiratory Diseases, Boston Children's Hospital, Boston, Mass

^cClinical Research Center, Boston Children's Hospital, Boston, Mass

^dDepartment of Pediatrics, Harvard Medical School, Boston, Mass

^eDivision of Respiratory Epidemiology, Channing Laboratory, Brigham and Women's Hospital, Boston, Mass

This work was conducted with support from Harvard Catalyst/The Harvard Clinical and Translational Science Center (National Institutes of Health Award UL1 RR 025758) and financial contributions from Harvard University and its affiliated academic health care centers. The content is solely the responsibility of the authors and does not necessarily represent the official views of Harvard Catalyst, Harvard University and its affiliated academic health care centers, the National Center for Research Resources, or the National Institutes of Health.

J. L. Friedlander is supported by grant T32 AI007512-25. The School Inner-City Asthma Study is supported by grants R01 AI 073964, R01 AI 073964-02S1, and K24 AI 106822 (PI: W. Phipatanakul).

Conflicts of interest: J. L. Friedlander, J. M. Gaffin, D. R. Gold, and W. Phipatanakul have received research support from the National Institutes of Health. L. S. Kopel has received research support from Aerocrine. A. Ozonoff has received consultancy fees from Roger Williams Medical Center. The rest of the authors declare they have no relevant conflicts of interest.

Received for publication February 20, 2013; revised May 8, 2013; accepted for publication June 19, 2013.

Available online August 5, 2013.

Cite this article as: Friedlander JL, Sheehan WJ, Baxi SN, Kopel LS, Gaffin JM, Ozonoff A, et al. Food allergy and increased asthma morbidity in a school-based inner-city asthma study. J Allergy Clin Immunol: In Practice 2013;1:479-84. <http://dx.doi.org/10.1016/j.jaip.2013.06.007>.

Corresponding author: Wanda Phipatanakul, MD, MS, Division of Immunology, Boston Children's Hospital, 300 Longwood Avenue, Boston, MA 02115. E-mail: wanda.phipatanakul@childrens.harvard.edu.

2213-2198/\$36.00

© 2013 American Academy of Allergy, Asthma & Immunology
<http://dx.doi.org/10.1016/j.jaip.2013.06.007>

Asthma affects approximately 18.7 million adults and 7 million children in the United States.^{1,2} Asthma prevalence is also higher for children than for adults, and for racial minorities.³

Abbreviations used

CI- Confidence interval

FEF₂₅₋₇₅- Forced expiratory flow 25% to 75% of forced vital capacityFEV₁- Forced expiratory volume in 1 second

FVC- Forced vital capacity

IgE- Immunoglobulin E

IQR- Interquartile range

OR- Odds ratio

SD- Standard deviation

SICAS- School Inner-City Asthma Study

In 2008, asthma accounted for an estimated 10.5 million lost school days in children.⁴ Food allergy prevalence in children is also increased; with an 18% increase in reported food allergy in children younger than 18 years old from 1997 to 2007.⁵ Studies in atopic children with food allergies have shown a higher risk for asthma development, and severe food allergy has been associated with greater odds of having a diagnosis of asthma.⁶⁻⁸ Children with food allergies and asthma are at increased risk of food-induced anaphylaxis and death.^{9,10} The interrelationship between food allergy and asthma morbidity, however, is not well understood. Recently, a general US population study demonstrated an association between food allergy and severe asthma exacerbations.¹¹ Less is known regarding the presence of food allergy as an independent risk factor for increased asthma morbidity in children, particularly for poor, urban environments. In our study, we aimed to investigate the relation between food allergy and asthma morbidity in urban students with asthma. Our *a priori* hypothesis was that a current diagnosis of food allergy would be a significant predictor of increased asthma morbidity in students with asthma in our school-based inner-city asthma cohort.

METHODS

In this analysis, 300 subjects with physician-diagnosed asthma were enrolled from 2008 to 2011 in the School Inner-City Asthma Study (SICAS), a prospective study of urban school-aged students in the Northeast. The comprehensive study design and methods for SICAS were previously published.¹² Briefly, students with asthma were screened and recruited from urban elementary schools. Eligibility requirements were modeled after other National Inner-City Asthma Studies,¹³ including physician-diagnosed asthma, along with the presence of wheezing, the current use of controller medicines for asthma, or unscheduled physician or health care visits for asthma in the 12 months before screening. Exclusion criteria included significant pulmonary disease other than asthma, significant cardiovascular disease that required daily medication, use of β -blocker medication, and an inability to complete study procedures. After obtaining informed consent, trained interviewers administered an extensive baseline survey to the child's caregiver, which included questions regarding demographics, medical history, and detailed sections about asthma morbidity and food allergy. The baseline survey was modeled after validated questionnaires from other inner-city asthma studies.¹³ Asthma morbidity outcomes included clinical symptoms, the effect on activities of daily living, the effect on the parent or other caregiver, resource utilization, and lung function measurements. The food allergy section included comprehensive symptoms experienced within

1 hour of food ingestion for reported foods. Our definition of IgE-mediated food allergy was consistent with other studies^{14,15} and included cutaneous (pruritus, urticaria, edema), gastrointestinal (mouth and/or throat itching, abdominal pain, vomiting), respiratory (throat tightness, cough, dyspnea, wheezing), and cardiovascular (hypotension, syncope) symptoms. The subjects were not considered to have food allergy if reported symptoms after food ingestion were not consistent with IgE-mediated food allergy. Pulmonary function testing (Koko spirometer; nSpire Health Inc, Longmont, Colo) was performed according to American Thoracic Society guidelines.¹⁶ All lung function results were analyzed by a study physician (J.M.G.) to ensure fulfillment of acceptable criteria. The study was approved by the Boston Children's Hospital and Brigham and Women's Hospital Institutional Review Board.

Statistical methods

The univariate analysis of the relation between food allergy variables and outcome measures used χ^2 analysis for categorical variables and for the independent *t* test or Wilcoxon rank sum test for continuous variables, when depending on evidence for or against normal distributions, respectively. Stepwise logistic regression was used to select multivariate models, while adjusting for potential confounders and examining interactions. Variables included in the final models satisfied a change-in-estimate criterion ($\leq 10\%$ in the odds ratio [OR] or β -coefficient estimate) or were significant at the $P < .05$ level. All analyses were conducted by using SAS v9.2 (SAS Institute Inc, Cary, NC).

RESULTS

Characteristics of the SICAS participants

Descriptive characteristics of study participants are presented in Table 1. Three hundred elementary school subjects were enrolled from June 2008 to November 2011. Fifty percent of the subjects were boys, with an overall cohort mean age of 7.9 years and an age range of 5-13 years. Thirty-six percent of the subjects were black, 34% Hispanic, 18% mixed, and fewer than 5% white. In this impoverished, primarily nonwhite cohort, 47% of the parents and caregivers of subjects who reported income had an annual household income of less than \$25,000, and 71% reported income less than \$45,000. There was a family history of asthma in 80% of the subjects, and a diagnosis of eczema in 50%. More than 20% of the subjects had frequent rescue medication use (≥ 2 times a week in the past 4 weeks). A fourth of the subjects had parents or caregivers who rated their child's asthma control as poor. More than a third of the subjects were exposed to at least one family member who smoked at home.

Food allergy characteristics

Seventy-three of the 300 subjects with asthma (24.3%) had physician-diagnosed food allergy. The percentage prevalence of individual food allergies is displayed in Figure 1. Of the 73 subjects with food allergy, peanut was the most prevalent (43.8%) followed by tree nuts (30.1%). Multiple food allergies were present in 49.3% of the subjects with food allergy ($n = 36$). We defined multiple food allergies as the presence of food allergies from 2 distinct food groups, consistent with other studies.¹⁷ For example, a subject who reported allergy to milk and peanut would be classified as having multiple food allergies, whereas a subject who reported allergy to only several tree nuts would not meet criteria for multiple food allergies.

TABLE I. Descriptive characteristics of study participants

Characteristic	
Total no. of subjects	300
Boys, no. (%)	151 (50.3)
Age (y), mean (range)	7.9 (5-13)
Race, no. (%)	
White	14 (4.7)
Black	108 (36.0)
Hispanic	103 (34.3)
Mixed	53 (17.7)
Other*	22 (7.4)
Annual household income, no. (%)†	
<\$25,000	118 (47.0)
\$25,000-\$44,999	60 (24.0)
>\$45,000	73 (29.2)
Family history of asthma, no. (%)	239 (79.7)
Diagnosis of eczema, no. (%)	145 (48.5)
Diagnosis of food allergy, no. (%)	73 (24.3)
Home tobacco smoke exposure, no. (%)‡	105 (35.0)
% predicted FEV ₁ , mean (SD)§	101.8 ± 19.3
FEV ₁ /FVC, mean (SD)§	0.87 ± 0.07
Dyspnea, no. (%)	36 (12.3)
Rescue medication use, no. (%)¶	64 (21.4)
Parent-rated poor asthma control, no. (%)#	74 (25.3)

FVC, Forced vital capacity.

*Includes Asian, Haitian, or Native American parents or caregivers of subjects.

†N = 251, because 49 subjects chose not to report household income.

‡Includes subjects with ≥1 family member who smokes at home.

§Spirometry data include 258 subjects who met established criteria described in methods.

||Shortness of breath ≥3 times a wk in the past 4 wk.

¶Rescue inhaler use ≥2 times a wk in the past 4 wk.

#Parent-rated assessment of asthma control in the past 4 wk.

The percentage prevalence of specific symptoms reported within 1 hour of food ingestion is displayed in Figure 2. Urticaria was most common (61%), followed by skin erythema (56.2%) and throat itching (45.2%). Respiratory symptoms were common, including dyspnea (34.2%), cough (28.8%), and wheezing (30.1%). Abdominal pain (24.7%) and vomiting (23.3%) were also commonly reported.

Any food allergy and asthma morbidity

The association between food allergy and asthma morbidity outcomes is presented in Tables II and III. All results in the tables represent multivariable models, which included adjustments for age, sex, race, annual household income, tobacco smoke exposure, and physician diagnosis of eczema. The subjects with any food allergy had almost 2 times increased risk of daytime symptoms (≥3 days with wheeze and/or cough in the past 2 weeks) ($P = .047$), more than 2 times the risk of lifetime hospitalization ($P = .005$), and weak associations with increased hospitalizations in the past 12 months ($P = .07$). Children with asthma and with any food allergy had 2 times the risk of asthma controller use compared with those without food allergy ($P = .03$). No significant association was seen with reported symptoms of dyspnea (shortness of breath ≥3 times a week in the past 4 weeks), parent-perceived asthma control, missed school days due to asthma, or unscheduled asthma visits to a provider. The percent predicted FEV₁ scores were lower in the

food allergy group (mean, 98.13% vs 102.99%; $P = .004$). FEV₁/FVC scores were also lower in the any food allergy group (mean, 0.855 vs 0.870; $P = .01$).

Multiple food allergies and asthma morbidity

The subjects with multiple food allergies had more than 3 times the increased risk of daytime symptoms ($P = .006$). These subjects had more than 5 times risk of lifetime hospitalization ($P = .0003$), more than 4 times increased risk of hospitalization in the past 12 months ($P = .007$), and more than 3.5 times increased risk of asthma-related hospitalization in the past 12 months ($P = .03$). Subjects with multiple food allergies had more than 2 times increased risk of asthma controller medication use ($P = .050$). The number of unscheduled visits to a health care provider for asthma was significantly higher in the multiple food allergy group (median, 4.5 vs 3.0; $P = .008$). Lung function was lower in the multiple food allergy group (percent predicted FEV₁ mean, 97.13% vs 102.99%; $P = .0007$), as were FEV₁/FVC scores (mean, 0.849 vs 0.870; $P = .01$). There were no significant associations seen between subjects with multiple food allergies and reported symptoms of dyspnea, parent-perceived asthma control, unscheduled asthma visits to a provider in the past 12 months, or percent predicted forced expiratory flow 25% to 75% of forced vital capacity (FEF₂₅₋₇₅) values.

DISCUSSION

The goal of our study was to determine whether the presence of food allergy is associated with increased asthma morbidity as an independent risk factor in elementary students from a school-based, poor, urban, primarily nonwhite asthma cohort. This study provides evidence for increased asthma morbidity in children with any food allergy, and this risk was higher in students with multiple food allergies. We found that students with asthma and multiple food allergies have significantly increased daytime asthma symptoms, asthma controller medication use, asthma-related hospitalizations, unscheduled health visits to a provider, and decreased lung function. These independent associations remained when adjusting for other atopic disease, including physician-diagnosed eczema, which suggests that concurrent food allergy diagnosis is an independent risk factor for increased asthma morbidity.

Peanut and tree nuts were the most prevalent food allergies in this school-aged cohort. The somewhat lower prevalence of cow's milk and egg allergy may be indicative of our older, elementary school-aged cohort. The higher overall prevalence of food allergy seen in children with asthma in our study is consistent with other national studies. Data from the National Health and Nutrition Examination Survey demonstrated increased prevalence of food sensitization in children with asthma compared with those without asthma.¹¹ In 2005, Wang et al¹⁸ investigated the effect of food allergen sensitization on asthma severity by using IgE measurements from serum samples obtained from the National Cooperative Inner City Asthma Study. Analysis of the results showed 45% of patients sensitized to at least one food and 26% of subjects with asthma with probable food allergy based on food allergen-specific IgE cutoffs. There was no report of clinical symptoms in this study. Wang et al¹⁸ found that children sensitized to at least one food had higher rates of asthma hospitalizations and required more corticosteroid medications, and concluded that food allergen sensitization may be a marker for increased asthma severity. Our study concurs with these

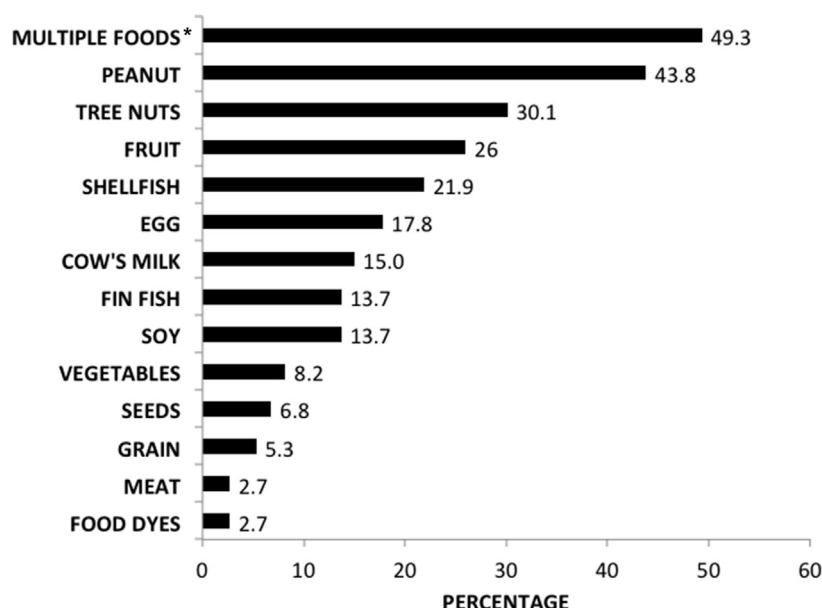


FIGURE 1. Percentage prevalence of food allergies (n = 73). *Includes subjects with food allergies from at least 2 of the above categories.

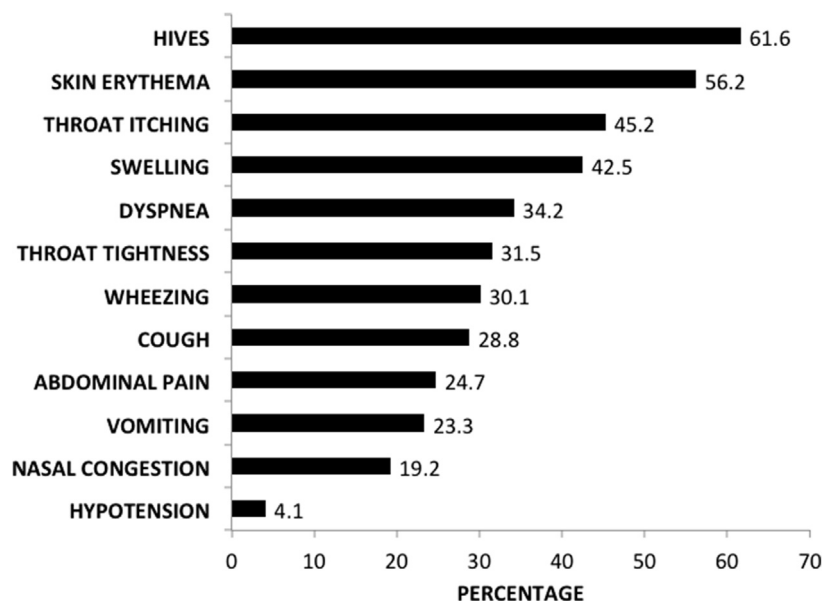


FIGURE 2. Symptoms experienced within 1 hour of food ingestion.

results and also adds the component of current clinical symptoms upon ingestion. Given that sensitization alone does not necessarily correlate with clinical allergy, our findings in this poor, urban elementary school cohort provides further evidence of food allergy as a marker for increased asthma morbidity in vulnerable at-risk populations. Recently, Krogulska et al¹⁹ demonstrated increased bronchial hyper responsiveness in children with food allergy, independent of whether or not respiratory symptoms were present. Malmberg et al²⁰ prospectively studied children with a history of positive cow's milk-specific IgE and found that at school age, these children showed signs of airway

inflammation, including increased exhaled nitric oxide levels and more pronounced bronchial responsiveness to histamine compared to controls without cow's milk sensitization.

Although we found an association between food allergy and multiple measures of asthma morbidity, this does not imply a causal relationship and was not the focus of our study. There is evidence for food-triggered asthma exacerbations, and results of the study by Liu et al¹¹ from the National Health and Nutrition Examination Survey investigation suggest that food allergy-triggered asthma exacerbations may be underrecognized. A recent study by Tepper et al²¹ found that infants sensitized to milk or

TABLE II. Association between the presence of food allergy and binary asthma morbidity outcomes*

Outcome	% Any food allergy (n = 73)	% No food allergy (n = 227)	Adjusted OR (CI)	P value	% Multiple food allergy (N = 36)	% No food allergy (N = 227)	Adjusted OR (CI)	P value
Increased daytime cough/wheeze†	32	21	1.95 (1.01-3.75)	.047	42	21	3.11 (1.38-7.00)	.006
Dyspnea‡	15	11	1.83 (0.76-4.41)	.18	14	11	1.44 (0.46-4.56)	.53
Perceived poor asthma control§	27	25	1.38 (0.71-2.67)	.34	25	25	1.10 (0.46-2.64)	.84
Any unscheduled asthma visits in the past year	42	44	0.77 (0.42-1.40)	.39	42	44	0.76 (0.35-1.64)	.48
Lifetime hospitalization	62	40	2.35 (1.30-4.24)	.005	78	40	5.08 (2.13-12.18)	.0003
Hospitalization in the past 12 mo	14	8	2.31 (0.94-5.72)	.07	22	8	4.10 (1.47-11.45)	.007
Hospitalization for asthma in the past 12 mo	10	7	1.91 (0.68-5.38)	.22	17	7	3.52 (1.12-11.03)	.03
Asthma controller medication use	74	58	1.99 (1.06-3.74)	.03	78	58	2.38 (1.00-5.66)	.050

OR, Odds ratio.

Note. Bolded data represents statistical significance.

*Multivariate models were adjusted for age, race, sex, annual household income, tobacco smoke exposure, and history of eczema.

†Three or more days with wheezing and/or cough in the past 2 wk.

‡Shortness of breath ≥3 times a week in the past 4 wk.

§Parent-rated assessment of asthma control in the past 4 wk.

TABLE III. Association between the presence of food allergy and continuous asthma morbidity outcomes*

Outcome	Any food allergy (n = 73)	No food allergy (n = 227)	P value	Multiple food allergy (n = 36)	No food allergy (n = 227)	P value
No. of asthma-related missed school days in past year, median (IQR)	4.0 (1.0-10.0)	3.0 (0.0-7.0)	.21	5.0 (2.0-10.8)	3.0 (0.0-7.0)	.10
No. of visits to provider in the past year, median (IQR)	4.0 (2.0-5.0)	3.0 (2.0-5.0)	.19	4.5 (3.0-6.0)	3.0 (2.0-5.0)	.008
% predicted FEV ₁ , mean (SD)	98.13 ± 21.82	102.99 ± 18.36	.004	97.13 ± 23.81	102.99 ± 18.36	.0007
FEV ₁ /FVC, mean (SD)	0.855 ± 0.0823	0.870 ± 0.0724	.01	0.849 ± 0.103	0.870 ± 0.0724	.01
% predicted FEF ₂₅₋₇₅ , mean (SD)	124.61 ± 168.36	112.99 ± 45.59	.73	146.18 ± 235.36	112.99 ± 45.59	.48

FEF₂₅₋₇₅, Forced expiratory flow 25% to 75% of forced vital capacity; FVC, forced vital capacity; IQR, interquartile range.

Note. Bolded data represents statistical significance.

*Multivariate models were adjusted for age, race, sex, annual household income, tobacco smoke exposure, and history of eczema.

egg allergens had increased airway responsiveness to methacholine when compared with controls without food sensitization. Previously, Bock²² studied respiratory reactions induced by food challenges in children with pulmonary disease and found that, of 410 children with a history of asthma, 279 (68%) reported food-induced asthma. The study revealed positive blinded food challenges in 60% of the 279 patients; 24% of those subjects developed wheezing during the challenge.²² Wheezing was usually present along with other nonrespiratory symptoms, however. More studies are needed to investigate the direct effect of food allergy on asthma exacerbations.

Our study revealed lower lung function in subjects with any or multiple food allergies, with significant differences seen in mean percent predicted FEV₁ scores and mean FEV₁/FVC ratios. Small airway differences were not seen. Small airway disease is a current area of interest, particularly in children with asthma and with normal FEV₁ and FEV₁/FVC values. The lack of significant differences seen in mean percent predicted FEF₂₅₋₇₅ values in our study may relate to the variability seen in other studies that used FEF₂₅₋₇₅ measurements.²³

Our study has several strengths, including a large sample of inner-city children with asthma; detailed survey phenotypic data, including the presence of physician-diagnosed food allergy; and specific current symptoms elicited upon food ingestion. We acknowledge that food allergy was not confirmed with double-

blind, placebo-controlled food challenges, the criterion standard in food allergy diagnosis, which was beyond the scope and focus of this study. However, the subjects did fulfill clinical criteria, including reported symptoms experienced within 1 hour, which were consistent with IgE-mediated food allergy and methods modeled from other studies that give reasonable diagnosis based on clinical algorithms.²⁴⁻²⁶ Results of our study suggest that understanding comorbid symptoms of food allergy and asthma morbidity should be further evaluated, particularly in a school-based setting. As in all survey studies, recall bias is possible. However, the addition of current reported symptoms of food allergy in association with current asthma morbidity is a strength. Our asthma definitions and outcomes were modeled after other National Institute of Allergy and Infectious Diseases funded inner-city asthma studies that focus on physician diagnosis and symptoms.^{13,27,28} We recognize that physician's diagnosis of asthma and symptoms may reflect reporting bias. However, both parental reports of wheeze and physician's diagnosis of asthma have consistently been associated with lower lung function, skin test reactivity, and airways responsiveness in pediatric epidemiologic asthma literature.²⁹ A parental report of the physician's diagnosis is a standard definition in respiratory epidemiology, is based on a standardized questionnaire, and is used by the National Center for Health Statistics and other government agencies in surveys of the US population. Physicians tend to

underdiagnose asthma in early childhood, and our results are likely conservative.³⁰

In addition, our study involved an urban, predominantly nonwhite elementary school-aged student population, and results may not be as generalizable to other asthmatic populations. However, this vulnerable group has been established to have significantly higher risk and morbidity, and relationships in this group are not well understood. Perhaps future school surveillance studies that evaluate food allergy and asthma comorbidity may be useful in furthering our understanding of 2 highly prevalent and allergic conditions that affect many poor, urban, youth.

CONCLUSION

We found increased prevalence of food allergies in poor, primarily nonwhite, inner-city school-aged students with asthma. We found independent risk factors of higher asthma morbidity in subjects with food allergies, including increased daytime asthma symptoms, hospitalizations, controller medication use, health care utilization, and decreased lung function. Based upon these findings, it is reasonable that children with asthma and food allergies may require increased surveillance by their physicians and caretakers to optimize asthma control.

Acknowledgments

We thank Lincoln Diagnostics for the gracious support in providing allergy skin testing supplies, and Greer Inc, for the gracious support in allergen skin testing reagents.

REFERENCES

1. Pleis JR, Ward BW, Lucas JW. Summary health statistics for U.S. adults: National Health Interview Survey, 2009. *Vital Health Stat* 10 2010;(249):1-207.
2. Bloom B, Cohen RA, Freeman G. Summary health statistics for U.S. children: National Health Interview Survey, 2009. *Vital Health Stat* 10 2010;(247):1-82.
3. Akinbami LJ, Moorman JE, Bailey C, Zahran HS, King M, Johnson CA, et al. Trends in asthma prevalence, health care use, and mortality in the United States, 2001-2010. *NCHS Data Brief* 2012;(94):1-8.
4. Akinbami LJ, Moorman JE, Liu X. Asthma prevalence, health care use, and mortality: United States, 2005-2009. *Natl Health Stat Report* 2011;(32):1-14.
5. Branum AM, Lukacs SL. Food allergy among children in the United States. *Pediatrics* 2009;124:1549-55.
6. Expert Panel Report 3 (EPR-3): Guidelines for the Diagnosis and Management of Asthma-Summary Report 2007. *J Allergy Clin Immunol* 2007;120(Suppl): S94-138.
7. Schroeder A, Kumar R, Pongracic JA, Sullivan CL, Caruso DM, Costello J, et al. Food allergy is associated with an increased risk of asthma. *Clin Exp Allergy* 2009;39:261-70.
8. Gaffin JM, Phipatanakul W. The role of indoor allergens in the development of asthma. *Curr Opin Allergy Clin Immunol* 2009;9:128-35.
9. Bock SA, Munoz-Furlong A, Sampson HA. Fatalities due to anaphylactic reactions to foods. *J Allergy Clin Immunol* 2001;107:191-3.
10. Roberts G, Patel N, Levi-Schaffer F, Habibi P, Lack G. Food allergy as a risk factor for life-threatening asthma in childhood: a case-controlled study. *J Allergy Clin Immunol* 2003;112:168-74.
11. Liu AH, Jaramillo R, Sicherer SH, Wood RA, Bock SA, Burks AW, et al. National prevalence and risk factors for food allergy and relationship to asthma: results from the National Health and Nutrition Examination Survey 2005-2006. *J Allergy Clin Immunol* 2010;126:798-806.e13.
12. Phipatanakul W, Bailey A, Hoffman EB, Sheehan WJ, Lane JP, Baxi S, et al. The school inner-city asthma study: design, methods, and lessons learned. *J Asthma* 2011;48:1007-14.
13. Mitchell H, Senturia Y, Gergen P, Baker D, Joseph C, McNiff-Mortimer K, et al. Design and methods of the National Cooperative Inner-City Asthma Study. *Pediatr Pulmonol* 1997;24:237-52.
14. Wang J. Management of the patient with multiple food allergies. *Curr Allergy Asthma Rep* 2010;10:271-7.
15. Wang J, Sampson HA. Food allergy. *J Clin Invest* 2011;121:827-35.
16. Miller MR, Crapo R, Hankinson J, Brusasco V, Burgos F, Casaburi R, et al. General considerations for lung function testing. *Eur Respir J* 2005;26:153-61.
17. Park JH, Ahn SS, Sicherer SH. Prevalence of allergy to multiple versus single foods in a pediatric food allergy referral practice. *J Allergy Clin Immunol* 2010;125:AB216.
18. Wang J, Visness CM, Sampson HA. Food allergen sensitization in inner-city children with asthma. *J Allergy Clin Immunol* 2005;115:1076-80.
19. Krogulska A, Dynowski J, Wasowska-Krolikowska K. Bronchial reactivity in schoolchildren allergic to food. *Ann Allergy Asthma Immunol* 2010;105: 31-8.
20. Malmberg LP, Saarinen KM, Pelkonen AS, Savilahti E, Makela MJ. Cow's milk allergy as a predictor of bronchial hyperresponsiveness and airway inflammation at school age. *Clin Exp Allergy* 2010;40:1491-7.
21. Tepper RS, Llapur CJ, Jones MH, Tiller C, Coates C, Kimmel R, et al. Expired nitric oxide and airway reactivity in infants at risk for asthma. *J Allergy Clin Immunol* 2008;122:760-5.
22. Bock SA. The incidence of severe adverse reactions to food in Colorado. *J Allergy Clin Immunol* 1992;90:683-5.
23. Bacharier LB, Strunk RC, Mauger D, White D, Lemanske RF, Sorkness CA. Classifying asthma severity in children mismatch between symptoms, medication use, and lung function. *Am J Respir Crit Care Med* 2004;170:426-32.
24. Gaffin JM, Sheehan WJ, Morrill J, Cinar M, Borrás Coughlin IM, Sawicki GS, et al. Tree nut allergy, egg allergy, and asthma in children. *Clin Pediatr (Phila)* 2011;50:133-9.
25. Stutius LM, Sheehan WJ, Rangsiethienchai P, Bharmatee A, Scott JE, Young MC, et al. Characterizing the relationship between sesame, coconut, and nut allergy in children. *Pediatr Allergy Immunol* 2010;21:1114-8.
26. Gupta RS, Springston EE, Smith B, Pongracic J, Holl JL, Warrier MR. Parent report of physician diagnosis in pediatric food allergy. *J Allergy Clin Immunol* 2013;131:150-6.
27. Morgan WJ, Crain EF, Gruchalla RS, O'Connor GT, Kattan M, Evans R III, et al. Results of a home-based environmental intervention among urban children with asthma. *N Engl J Med* 2004;351:1068-80.
28. Busse WW, Morgan WJ, Gergen PJ, Mitchell HE, Gern JE, Liu AH, et al. Randomized trial of omalizumab (anti-IgE) for asthma in inner-city children. *N Engl J Med* 2011;364:1005-15.
29. Gold DR, Wypij D, Wang X, Speizer FE, Pugh M, Ware JH, et al. Gender- and race-specific effects of asthma and wheeze on level and growth of lung function in children in six U.S. cities. *Am J Respir Crit Care Med* 2004;149:1198-208.
30. Weiss ST. Epidemiology and heterogeneity of asthma. *Ann Allergy Asthma Immunol* 2001;87(Suppl 1):5-8.