

Body mass index and acute asthma severity among children presenting to the emergency department

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To determine the prevalence of obesity among children presenting to the emergency department (ED) with acute asthma, and to examine the relationship between body mass index (BMI) and acute asthma severity in the ED setting. We analyzed data from a multicenter prospective cohort study during 1997–1998; 44 ED in 17 US states and two Canadian provinces enrolled 672 patients, age 5–17, with acute asthma. BMI and Pulmonary Index were collected in the ED. We defined overweight and obesity using age, sex, and race-specific BMI values from national and international databases. The prevalence of obesity was significantly higher among ED patients with acute asthma as compared with children from the general population (23% vs. 9–15%; $p < 0.001$). Obese children with acute asthma did not differ from their non-obese counterparts, by demographic factors or chronic asthma severity (all $p > 0.2$). Initial Pulmonary Index was the same across underweight, intermediate, and obese groups (3.7 ± 2.4 , 3.8 ± 2.2 , 3.7 ± 2.3 ; $p = 0.70$). Admission status also did not vary across groups (22%, 22% and 23%; $p = 0.98$). Stratifying the analysis by age group and sex did not change these results. The prevalence of obesity among children presenting to the ED with acute asthma was significantly higher compared with children from the general population. BMI was not associated with markers of chronic and acute asthma severity. The results of this study support a positive association between obesity and asthma, and suggest that asthma exacerbations among obese children are very similar to those experienced by other children.

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The prevalence of childhood obesity, defined as body mass index (BMI) ≥ 95 th percentile based on historical reference populations, is estimated to be approximately 17% in the US (1). This rate that has more than tripled over the past 25 yr (2). Likewise, the prevalence of childhood asthma has increased from 3.5% in 1980 to 8.5% in 2004 (3). The concomitant rise in both obesity and asthma has made these two conditions among the most common chronic diseases in childhood (4, 5).

There are consistent epidemiological data that confirm the relationship between obesity and asthma diagnosis in children and adolescents

(6–11). Furthermore, obesity has identified as a risk factor for developing asthma in several longitudinal studies in both children (12–20) and adults (21, 22). Several studies have also evaluated the association of obesity with chronic asthma severity and control in children (23–29); however, prospective studies of the association of obesity with acute asthma severity have been limited to adults (30, 31) or critically ill children (32). Although one single-center retrospective study evaluated the association between obesity and acute asthma severity (33), there have been no prior prospective studies of the relationship

between BMI and a broader range of acute asthma severity in children.

The primary aims of this multicenter, prospective study were to measure the prevalence of obesity among children presenting to the emergency department (ED) with acute asthma, and to examine the relationship between BMI and acute and chronic asthma severity in the ED setting.

Materials and methods

Study design and setting

This study analyzes data from a prospective cohort study performed during 1997–1998, as part of the Multicenter Airway Research Collaboration (MARC) (34). MARC is part of the Emergency Medicine Network (EMNet), a collaboration of 198 participating EDs (<http://www.emnet-usa.org>).

Using a standard protocol, investigators at 44 EDs in 17 US states and two Canadian provinces provided 24-h per day coverage for a median of 2 wk and enrolled 1,184 patients with acute asthma. All patients were managed at the discretion of the treating physician. Inclusion criteria were physician diagnosis of acute asthma; age 2–17; and informed consent of the parent or guardian. Twenty-five patients who were emancipated minors gave informed consent and were interviewed. We excluded repeat visits by individual subjects; children age 2–4 ($n = 353$); those missing weight or height ($n = 143$); and those of race/ethnicity other than white, black or Hispanic because of the small number of children in this group ($n = 16$). After these exclusions, 672 children remained. The Institutional Review Board at each of the 44 participating hospitals approved the study.

Data collection

The ED interview assessed self-reported weight, height, demographic characteristics, asthma history, and details of their current asthma exacerbation. Data on ED management and disposition were obtained by chart review. Follow-up data were collected by telephone interview 2 wk later and included details of any urgent asthma visits, changes in medical management, and current asthma symptoms; 88% of patients were successfully contacted ($n = 588$). Site investigators reviewed all forms before submission to the EMNet Coordinating Center in Boston, where they underwent further review by trained personnel and then double data entry.

We assigned primary care provider status on the basis of the following question: ‘Do you have a primary care provider (such as a family doctor, internist, or nurse practitioner)?’; if yes, patients were asked to provide the name and address of their primary care provider. Median family income was estimated using patients’ home ZIP codes (35).

Body mass index, defined as weight in kilograms divided by height in meters squared (kg/m^2), was used as the primary measure of obesity in children, and is a validated measure of adiposity in children (36, 37). Using age, sex, and race-specific BMI values derived from nine large US epidemiologic studies conducted between 1973–1994 (38), underweight was defined as BMI < 5th percentile, overweight was defined as BMI $\geq$ 85th percentile, and obesity as BMI $\geq$ 95th percentile. Additionally, we compared this US-based method to an internationally valid method derived by Cole et al. For this method, overweight and obesity were defined by averaging centile curves obtained from six nationally representative datasets of body mass indices in childhood from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States, and designed to pass through 25 kg/m^2 and 30 kg/m^2 at age 18 (39).

Pulmonary Index scores were calculated using respiratory rate, accessory muscle use, wheezing, and I:E ratio. Based on a scale of 0–3 for each component of the Pulmonary Index, we calculated a total Pulmonary Index score, out of a maximum of 12 (40). Imputed values were used to calculate the Pulmonary Index score when one of the elements (i.e., respiratory rate, accessory muscle use, wheezing, and I:E ratio) was missing; patients missing more than one of the parameters were not assigned a Pulmonary Index score. Relapse was defined as any urgent visit to an ED or clinic for worsening of asthma during the 2-wk follow-up period. Post-ED treatment failure was assigned to patients who reported ‘severe symptom’ during the preceding 24 h on at least one of two questions (i.e., asthma symptoms ‘most of the time’ or ‘severe’ discomfort and distress because of their asthma) or who stated that their asthma was ‘about the same’ or worse than at the time of their ED presentation. The ‘severe symptoms’ classification also was used to characterize the 24 h before ED presentation.

Statistical analysis

All analyses were performed using STATA 10.0 (StataCorp, College Station, TX, USA). We present data as proportions [with 95% confi-

dence intervals (CI)], means [with standard deviation (s.d.)], or medians [with interquartile range (IQR)]. The prevalence of obesity in the study population was compared with the prevalence of obesity among children from the general population, as reported in several national databases (38). Underweight, intermediate weight, overweight, and obese patients were compared by contingency table methods, analysis of variance, or Kruskal–Wallis test, as appropriate. All p-values are two-sided, with $p < 0.05$ considered statistically significant.

Results

The overall prevalence of obesity (BMI ≥ 95 th percentile for age and sex) among our sample of children who presented to the ED with acute asthma was 23% (95% CI, 20–26%), which was significantly greater ($p < 0.001$) than reported rates (9–15%) for children in the general population around the time of data collection (38).

Additionally, the prevalence of obesity in our sample was higher in boys (26%) than girls (19%) and children age 5–11 yr (26%) than adolescents age 12 to 17 yr (16%). Stratifying the

analysis by median family income in quartiles ($< \$21,858$; $\$21,858$ – $28,581$; $\$28,582$ – $36,607$; $> \$36,607$), the prevalence of obesity was found to be similar among all groups (24%, 21%, 27% and 20% respectively; $p = 0.46$), and consistently higher than the general population.

The prevalence of overweight (BMI ≥ 85 th percentile for age and sex) among ED children with acute asthma was 39%, significantly greater ($p < 0.001$) than children from the general population where the prevalence of overweight was approximately 25% (41). In our sample, 40% of children and 34% of adolescents in our sample were found to be overweight.

The demographic and chronic asthma characteristics of the study population are described in Table 1. There were no significant differences by sex, race-ethnicity, years of parental education, household income, insurance status or primary care provider status across BMI distribution (all $p > 0.05$). Also, obese subjects did not differ by several markers of chronic asthma severity, such as history of prior steroid use, prior hospitalization, or prior intubation for asthma (all $p > 0.05$). We did not find any association between obesity and number of urgent clinic

Table 1. Demographic and chronic asthma characteristics of children with acute asthma, according to body mass index

	Underweight (n = 65)	Intermediate weight (n = 454)	Obesity (n = 153)	p-value
Demographic factors				
Age (yr), mean $\pm$ s.d.	8.9 $\pm$ 2.9	10.5 $\pm$ 3.6	9.7 $\pm$ 3.4	<0.001
Female (%)	43	46	36	0.09
Race/ethnicity (%)				
White	23	22	21	0.20
Black	58	54	63	
Hispanic	18	24	16	
High school graduate (%)	69	71	72	0.85
Estimated household income (\$), median (IQR)	27,527 (20,243–36,608)	28,582 (21,935–37,056)	29,401 (21,858–36,583)	0.60
Insurance status (%)				
Private	36	40	40	0.99
Medicaid	33	30	32	
Other public	14	13	12	
None	17	17	16	
Primary care provider status (%)*	89	89	91	0.84
Chronic asthma factors				
Ever taken steroid medicine for asthma (%)	65	73	79	0.08
Ever hospitalized for asthma (%)	68	62	54	0.12
Ever intubated for asthma (%)	8	6	4	0.51
Inhaled β -agonist during past 4 wk (%)	77s	78	76	0.83
Inhaled cromolyn during past 4 wk (%)	31	29	26	0.73
Inhaled corticosteroid during past 4 wk (%)	22	27	23	0.48
Other asthma medication during past 4 wk (%)	17	18	19	0.91
No. urgent clinic visits in past year, median (IQR)	1 (0–3)	1 (0–3)	1 (0–3)	0.82
No. of ED visits in past year, median (IQR)	2 (1–5)	2 (0–4)	2 (1–4)	0.25
Admitted for asthma in past year (%)	28	25	26	0.90
ED usual site for problem asthma care (%)	66	66	64	0.95

IQR, interquartile range; ED, emergency department.

*Based on response to whether the child currently has a primary care physician.

visits, ED visits and admissions for acute asthma in the past year. Stratifying the analysis by age group, sex, or ED disposition and combining overweight with obese children did not materially change these results (data not shown).

Body mass index also was not related with acute asthma severity (Table 2). Initial Pulmonary Index was the same across underweight, intermediate, and obese groups. Admission status was similar across groups, and there were no significant differences in hospital length of stay. At 2-wk follow-up, relapse and post-ED treatment failure did not differ according to BMI (Table 2). Stratifying the analysis by age group, sex, or admission status and combining overweight with obese children did not materially change these results (data not shown).

Comparing the 672 children with height/weight to the 143 missing height/weight (who were excluded from analysis), a few differences were observed. Children with height/weight were older (10 ± 4 yr vs. 8 ± 3 yr; $p < 0.001$). They also were more likely to be white (22% vs. 8%) and less likely to be black (57% vs. 67%; $p = 0.001$). Their parents were more likely to have completed a high school education (71% vs.

61%; $p = 0.03$) and they had a higher estimated household income (median: 28,582 vs. 25,175; $p < 0.001$). While the children with height/weight had lower initial respiratory rates (mean: 28 ± 8 vs. 34 ± 11 ; $p < 0.001$) and higher initial oxygen saturation (96 ± 4 vs. 94 ± 6 ; $p = 0.001$), the two groups did not differ by chronic or other acute asthma characteristics. ED management and outcomes also were similar between the two groups.

In an alternate analysis using international obesity criteria, as reported by Cole et al. (39), the overall prevalence of obesity among our sample of children with acute asthma was 40%, and the prevalence of overweight was 45%. Although these rates were much higher than the primary analysis with these different BMI thresholds, the associations between overweight/obesity and demographics, chronic asthma characteristics, and acute asthma severity were not materially different (data not shown).

Discussion

The prevalence of obesity among a diverse sample of children presenting to the ED with

Table 2. Acute asthma characteristics, according to body mass index

	Underweight (n = 65)	Intermediate weight (n = 454)	Obesity (n = 153)	p-value
Presentation				
Duration of symptoms (%)				
<24 h	65	62	59	0.68
≥24 h	35	38	41	
No. inhaled β -agonist puffs within 6 h of ED				
Median (IQR)*	3 (0–10)	4 (0–12)	3 (0–8)	0.21
Severe symptoms (%)†	55	66	64	0.18
Initial respiratory rate (breaths/min), mean $\pm$ s.d.	29 ± 8	28 ± 8	28 ± 8	0.34
Initial O ₂ saturation, mean $\pm$ s.d.	96 ± 3	96 ± 4	96 ± 3	0.74
Pulmonary Index, mean $\pm$ s.d.†	3.7 ± 2.4	3.8 ± 2.2	3.7 ± 2.3	0.70
ED Course				
No. inhaled β -agonists in first hour, mean $\pm$ s.d.*	1.8 ± 1.1	1.8 ± 1.1	1.9 ± 1.1	0.51
No. of inhaled β -agonists over ED stay, mean $\pm$ s.d.*	3.2 ± 2.3	3.1 ± 2.1	3.2 ± 3.0	0.79
Given steroid treatment (%)	80	82	85	0.65
Received other asthma treatments in the ED (%)	42	40	41	0.95
ED length-of-stay (min), median (IQR)	149 (104–208)	144 (110–205)	140 (108–190)	0.69
ED disposition (%)				
Sent home	78	78	77	0.59
Admitted	22	22	23	
Hospital length of stay (days), median (IQR)	3 (2–3)	2 (1–3)	2 (2–3)	0.99
Sent home on systemic corticosteroids (%)‡	76	76	77	0.99
Post-ED course§				
Relapse within 48 h (%)	8	4	6	0.30
Relapse within 2 wk (%)	10	8	13	0.25
Failure (%)†	8	13	8	0.26

ED, emergency department; IQR, interquartile range.

*Each nebulizer treatment was counted as equivalent to six 'puffs' from a metered-dose inhaler.

†See Materials and methods for details.

‡Restricted to patients sent home from ED (n = 522).

§Restricted to patients with two-week telephone follow-up (n = 588).

acute asthma (23%) was significantly higher compared with children from the general population (9–15%). Similarly, the prevalence of overweight (39%) was found to be significantly higher among ED children with acute asthma, as compared with children from the general population (25%). Despite these clear differences, children presenting to the ED with acute asthma did not differ across the BMI distribution by demographic factors or several markers of chronic and acute asthma severity.

There is growing concern about increasing childhood obesity in the US (1, 2). Using 95th percentile BMI as the cutoff, Rosner et al. reported the prevalence of childhood obesity from several national databases in the mid-1990s to be between 9 and 15% depending on sex and race/ethnicity (38). In prior studies that assessed the relationship between obesity and asthma in children, the prevalence of obesity was found to be 1.5–2.5 times higher in those with physician-diagnosed asthma, compared with those without asthma (6–11).

In the present study, the prevalence of obesity in children presenting to the ED with acute asthma was found to be similar to the prevalence of obesity among those with physician-diagnosed asthma from the general population (23% vs 21–30%), but significantly higher compared with all children in the general population (23% vs 9–15%). This association is consistent with previous studies that found obesity is associated with prevalent asthma (6–11). As in many prior studies, the temporal relation between these two conditions cannot be established using our study design; thus, we are unable to determine if obesity preceded or followed asthma onset. Prior prospective cohort studies suggest that obesity is associated with increased asthma incidence in children (12–17), although this association may vary by sex (12, 14, 17) and may be more complex than initially described (18, 19).

Because asthma is a common disease in the general population that still lacks a universally accepted definition, asthma overdiagnosis may be common (42). Overdiagnosis of asthma among obese individuals would complicate interpretation of the apparent relationship between obesity and asthma. On the other hand, high BMI has been identified as a risk factor for asthma *underdiagnosis* in adolescents (43). Additionally, preliminary data suggest genotypic differences in obese vs. non-obese adults with asthma (44); the relevance of these findings to children is uncertain (45). Our data demonstrate that obese children with physician-diagnosed asthma have remarkably similar presentations

of acute exacerbation, which suggests that asthma overdiagnosis in obese children is probably uncommon, at least among those who visit the ED for emergency care. Recent data suggest that obesity does not confound the diagnosis of asthma (46). Nonetheless, we believe that this methodologic issue merits further attention.

Prior epidemiologic data on the relationship between obesity and chronic asthma severity and control in children are limited and provide conflicting information. One study of inner-city children supported an association between high BMI and increased chronic asthma severity (e.g., pulmonary function tests and number of asthma medications) (6), while other studies did not find an association (7, 24, 25). In contrast, several studies did find an association between obesity and some markers of worse asthma control (e.g., activity limitations and school days missed) (6, 23, 24, 26–29), but reported association with other markers of control, in particular ED visits and hospitalizations, is less clear (6, 23, 25, 26).

Results may differ because of the different, and still evolving, ways in which severity and control are classified (47). For instance, if obesity increases the frequency of asthma exacerbation, then this would increase chronic asthma severity classification, but if in the treatment phase, would lead to classification of poor control. As this study enrolls children at the time of asthma exacerbation, the analysis is better designed to assess acute asthma severity, than chronic asthma severity or control. Additionally, differences in measurement of obesity, especially changes over time, may also affect comparison of our results with other studies.

We present the first multicenter or prospective study to examine the association between BMI and acute asthma severity in children. Several measures of acute asthma severity, such as Pulmonary Index and admission status, did not vary across BMI distribution. These results differ from a recent single-center, retrospective study, which found an association between obesity and hospital admission rate in children presenting to the ED with acute asthma (33). Two recent studies of adults presenting to the ED with acute asthma also reached different conclusions; Rodrigo et al. showed an association between BMI and acute asthma severity in the severe subset of patients in their Uruguayan ED (31), while Thomson et al. found no association in a multicenter study that included all levels of acute asthma severity (30). Also of potential relevance, Carroll et al. found an association between obesity and asthma severity in critically ill children with status asthmaticus (32), but our

results did not confirm this finding. Even when we restricted our analysis to admitted patients, there were no significant associations between obesity and any of the markers of acute asthma severity.

Regardless of the causal nature of the association between obesity and asthma, the high prevalence of children with comorbid obesity and asthma is an important public health problem. In this study, we found that 23% of children presenting to the ED with acute asthma had comorbid obesity. Pediatricians should be aware of the association between obesity and asthma, and initiate a multidisciplinary approach for prevention and treatment of both conditions. Whether obesity leads to childhood asthma, or asthma leads to obesity remains unclear; the concomitant presentation of both diseases warrants further detailed examination. Additionally, a recent meta-analysis suggests that weight loss may reduce or mitigate asthma in adults (48), but the reversibility of asthma in children remains to be clarified.

This study has several potential limitations. Most importantly, our study lacks a comparison group from the ED to compare their obesity prevalence with that of the ED asthma population. Specifically, we did not measure the prevalence of obesity in ED children without asthma exacerbation, and national surveys were used to estimate the prevalence in the general population. Obese children tend to go more often to the ED than non-obese children because the prevalence of obesity is higher among individuals with a low socioeconomic status (49). However, the prevalence of obesity among children presenting to the ED with acute asthma appeared to be high, regardless of the socioeconomic status. For example, obesity was present in 24% of ED asthmatic children from lowest income households, and 20% among those from the highest income households. Additionally, because our outcomes were primarily symptom-based, we were unable to distinguish whether the high prevalence of obesity in children presenting to the ED with asthma exacerbation may have been related to either increased lung inflammation or increased symptoms with similar underlying inflammation in obese children with asthma.

Another potential limitation is the use of self-reported height and weight during the ED interview to calculate BMI. Although prior data suggests that BMI calculated from self-reported height and weight may be a valid indicator of obesity (50, 51), reliance on self-report may underestimate the true prevalence of obesity and introduce a source of imprecision in our measure-

ment (52). Additionally, while we did not specifically measure diet or activity in this study, the risk of obesity is a product of changes in diet and changes in overall activity. BMI was not recorded for 143 enrolled children, and demographic differences may have biased the results. However, these excluded children did not materially differ from the study sample by major chronic or acute asthma characteristics (see Results).

Our study included the outcome of Pulmonary Index, a clinical rather than function score, which was recorded by multiple observers. However, Pulmonary Index has shown excellent inter-observer agreement and objective correlation with pulmonary function testing in the early assessment of children with acute asthma (40). Additionally, use of a validated clinical score may be more reliable than spirometry, which is not reproducible during asthma exacerbation (53). Although many instruments, including the Pulmonary Index need to be re-validated in a contemporary population, over two decades of experience with this instrument, helps in comparison to prior studies. Criteria for hospital admission may have varied by site, which may limit the validity of this outcome. However, in a prior report, we demonstrated that we could accurately predict hospital admission for asthma exacerbation across the 44 sites (54). Finally, our population included only children presenting to the ED with acute asthma, so the results of this study may not be applicable to a more general population of children.

In conclusion, the prevalence of obesity and overweight among children presenting to the ED with acute asthma was significantly higher compared with children from the general population. BMI was not associated with several measures of chronic and acute asthma severity in our patient sample. The results of this study suggest that asthma exacerbations among obese children are very similar to those experienced by other children. Further elucidation of differences in the asthma phenotype of obese compared with non-obese children may help to improve diagnosis and control of asthma in this important subset of patients.

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References

1. OGDEN CL, CARROLL MD, CURTIN LR, McDOWELL MA, TABAK CJ, FLEGAL KM. Prevalence of overweight and obesity in the United States, 1999–2004. *JAMA* 2006; 295: 1549–55.
2. OGDEN CL, CARROLL MD, FLEGAL KM. Epidemiologic trends in overweight and obesity. *Endocrinol Metab Clin North Am* 2003; 32: 741–60.
3. MOORMAN JE, RUDD RA, JOHNSON CA, et al. Centers for Disease Control and Prevention (CDC). National surveillance for asthma—United States, 1980–2004. *MMWR Surveill Summ* 2007; 56: 1–54.
4. STORY RE. Asthma and obesity in children. *Curr Opin Pediatr* 2007; 19: 680–4.
5. FORD ES. The epidemiology of obesity and asthma. *J Allergy Clin Immunol* 2005; 115: 897–909.
6. LUDER E, MELNIK TA, DiMAIO M. Association of being overweight with greater asthma symptoms in inner city black and hispanic children. *J Pediatr* 1998; 132: 699–703.
7. GENNUSO J, EPSTEIN LH, PALUCH RA, CERNY F. The relationship between asthma and obesity in urban minority children and adolescents. *Arch Pediatr Adolesc Med* 1998; 152: 1197–200.
8. HONG SJ, LEE MS, LEE SY, et al. High body mass index and dietary pattern are associated with childhood asthma. *Pediatr Pulmonol* 2006; 41: 1118–24.
9. KWON HL, ORTIZ B, SWANER R, et al. Childhood asthma and extreme values of body mass index: the Harlem Children's Zone Asthma Initiative. *J Urban Health* 2006; 83: 421–33.
10. JACOBSON JS, MELLINS RB, GARFINKEL R, et al. Asthma, body mass, gender, and Hispanic national origin among 517 preschool children in New York City. *Allergy* 2008; 63: 87–94.
11. ABRAMSON NW, WAMBOLDT FS, MANSELL AL, CARTER R, FEDERICO MJ, WAMBOLDT MZ. Frequency and correlates of overweight status in adolescent asthma. *J Asthma* 2008; 45: 135–9.
12. CASTRO-RODRÍGUEZ JA, HOLBERG CJ, MORGAN WJ, WRIGHT AL, MARTINEZ FD. Increased incidence of asthma-like symptoms in girls who become overweight or obese during the school years. *Am J Respir Crit Care Med* 2001; 163: 1344–9.
13. GOLD DR, DAMOKOSH AI, DOCKERY DW, BERKEY CS. Body-mass index as a predictor of incident asthma in a prospective cohort of children. *Pediatr Pulmonol* 2003; 36: 514–21.
14. GILLILAND FD, BERHANE K, ISLAM T, et al. Obesity and the risk of newly diagnosed asthma in school-age children. *Am J Epidemiol* 2003; 158: 406–15.
15. GUERRA S, WRIGHT AL, MORGAN WJ, SHERRILL DL, HOLBERG CJ, MARTINEZ FD. Persistence of asthma symptoms during adolescence: role of obesity and age at onset of puberty. *Am J Respir Crit Care Med* 2004; 170: 78–85.
16. SIN DD, SPIER S, SVENSON LW, et al. The relationship between birth weight and childhood asthma: a population-based cohort study. *Arch Pediatr Adolesc Med* 2004; 158: 60–4.
17. MANNINO DM, MOTT J, FERDINANDS JM, et al. Boys with high body masses have an increased risk of developing asthma: findings from the National Longitudinal Survey of Youth (NLSY). *Int J Obes* 2006; 30: 6–13.
18. ENELI IU, KARMAUS WK, DAVIS S, KUEHR J. Airway hyperresponsiveness and body mass index: the Child Health and Environment Cohort Study in Hesse, Germany. *Pediatr Pulmonol* 2006; 41: 530–7.
19. ELKEMANS M, MOMMERS M, DE VRIES SI, et al. Asthmatic symptoms, physical activity, and overweight in young children: a cohort study. *Pediatrics* 2008; 121: e666–72.
20. REMES ST, PATEL SP, HARTIKAINEN AL, JARVELIN MR, PEKKANEN J. High birth weight, asthma and atopy at the age of 16 yr. *Pediatr Allergy Immunol* 2008; 19: 541–3.
21. CAMARGO CA JR, WEISS ST, ZHANG S, WILLETT WC, SPEIZER FE. Prospective study of body mass index, weight change, and risk of adult-onset asthma in women. *Arch Intern Med* 1999; 159: 2582–8.
22. BEUTHER DA, SUTHERLAND ER. Overweight, obesity and incident asthma: a meta-analysis of prospective epidemiologic studies. *Am J Respir Crit Care Med* 2007; 175: 661–6.
23. BELAMARICH PF, LUDER E, KATTAN M, et al. Do obese inner-city children with asthma have more symptoms than nonobese children with asthma? *Pediatrics* 2000; 106: 1436–41.
24. PIANOSI PT, DAVIS HS. Determinants of physical fitness in children with asthma. *Pediatrics* 2004; 113: e225–9.
25. KWONG KY, RHANDHAWA I, SAXENA J, MORPHEW T, JONES CA. Ability to control persistent asthma in obese versus non-obese children enrolled in an asthma-specific disease management program (breathmobile). *J Asthma* 2006; 43: 661–6.
26. VARGAS PA, PERRY TT, ROBLES E, et al. Relationship of body mass index with asthma indicators in head start children. *Ann Allergy Asthma Immunol* 2007; 99: 22–8.
27. BLANDON VIJIL V, DEL RIO NAVARRO B, BERBER ESLAVA A, SIENRA MONGE JJ. Quality of life in pediatric patients with asthma with or without obesity: a pilot study. *Allergol Immunopathol* 2004; 32: 259–64.
28. VAN GENT R, VAN DER ENT CK, ROVERS MM, KIMPEN JL, VAN ESSEN-ZANDVLIET LE, DE MEER G. Excessive body weight is associated with additional loss of quality of life in children with asthma. *J Allergy Clin Immunol* 2007; 119: 591–6.
29. OWNBY DR, ZORATTI E, PETERSON EL, STRINGER S, JOHNSON CC. Gender differences in the association of overweight and asthma morbidity among urban adolescents with asthma. *Pediatr Allergy Immunol* 2008; : . (In press).
30. THOMSON CC, CLARK S, CAMARGO CA JR, MARC INVESTIGATORS. Body mass index and asthma severity among adults presenting to the emergency department. *Chest* 2003; 124: 795–802.
31. RODRIGO GJ, PLAZA V. Body mass index and response to emergency department treatment in adults with severe asthma exacerbations: a prospective cohort study. *Chest* 2007; 132: 1513–9.
32. CARROLL CL, BHANDARI A, ZUCKER AR, SCHRAMM CM. Childhood obesity increases duration of therapy during severe asthma exacerbations. *Pediatr Crit Care Med* 2006; 7: 527–31.
33. CARROLL CL, STOLTZ P, RAYKOV N, SMITH SR, ZUCKER AR. Childhood overweight increases hospital admission rates for asthma. *Pediatrics* 2007; 120: 734–40.
34. CAMARGO CA JR. Acute asthma among children presenting to the emergency department: the Multicenter

- Asthma Research Collaboration [abstract]. *Acad Emerg Med* 1998; 5: 380.
35. CACI MARKETING SYSTEMS. *The Sourcebook of ZIP Code Demographics*, 13th edn. VA: Fairfax, 1998.
 36. PIETROBELLI A, FAITH MS, ALLISON DB, GALLAGHER D, CHIUMELLO G, HEYMSFIELD SB. Body mass index as a measure of adiposity among children and adolescents: a validation study. *J Pediatr* 1998; 132: 204–10.
 37. FLEGAL KM, TABAK CJ, OGDEN CL. Overweight in children: definitions and interpretation. *Health Educ Res* 2006; 21: 755–60.
 38. ROSNER B, PRINEAS R, LOGGIE J, DANIELS SR. Percentiles for body mass index in U.S. children 5 to 17 years of age. *J Pediatr* 1998; 132: 211–22.
 39. COLE TJ, BELLIZZI MC, FLEGAL KM, DIETZ WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; 320: 1240–3.
 40. BECKER AB, NELSON NA, SIMONS FE. The pulmonary index: assessment of a clinical score of asthma. *Am J Dis Child* 1984; 138: 574–6.
 41. TROIANO RP, FLEGAL KM. Overweight children and adolescents: description, epidemiology, and demographics. *Pediatrics* 1998; 101: 497–504.
 42. VEERARAGHAVAN S, SHARMA O. Diagnostic pitfalls in asthma. *Curr Opin Pulm Med* 1998; 4: 36–9.
 43. SIERSTED HC, BOLDSSEN J, HANSEN H, MOSTGAARD G, HYLDEBRANT N. Population based study of risk factors for underdiagnosis of asthma in adolescence: Odense schoolchild study. *BMJ* 1998; 316: 651–7.
 44. BARR RG, COOPER DM, SPEIZER FE, DRAZEN JM, CAMARGO CA JR. Beta(2)-adrenoceptor polymorphism and body mass index are associated with adult-onset asthma in sedentary but not active women. *Chest* 2001; 120: 1474–9.
 45. MATRICARDI PM, GRÜBER C, WAHN U, LAU S. The asthma-obesity link in childhood: open questions, complex evidence, a few answers only. *Clin Exp Allergy* 2007; 37: 476–84.
 46. AARON SD, VANDEMHEEN K, BOULET L, et al. Misclassification of asthma in obese and non-obese subjects (abstract). *Am J Resp Crit Care Med* 2008; 177 (Suppl.): A833.
 47. NATIONAL ASTHMA EDUCATION AND PREVENTION PROGRAM. Expert Panel Report 3 (EPR-3): Guidelines for the Diagnosis and Management of Asthma-Summary Report 2007. *J Allergy Clin Immunol* 2007; 120: S94–138.
 48. ENELI IU, SKYBO T, CAMARGO CA JR. Weight loss and asthma: a systematic review. *Thorax* 2008; 63: 671–6.
 49. SHREWSBURY V, WARDLE J. Socioeconomic status and adiposity in childhood: a systematic review of cross-sectional studies 1990–2005. *Obesity* 2008; 16: 275–84.
 50. BANACH A, WADE TJ, CAIRNEY J, HAY JA, FAUGHT BE, O'LEARY DD. Comparison of anthropometry and parent-reported height and weight among nine year olds. *Can J Public Health* 2007; 98: 251–3.
 51. DUBOIS L, GIRAD M. Accuracy of maternal reports of pre-schoolers' weights and heights as estimates of BMI values. *Int J Epidemiol* 2007; 36: 132–8.
 52. SHERRY B, JEFFERDS ME, GRUMMER-STRAWN LM. Accuracy of adolescent self-report of height and weight in assessing overweight status: a literature review. *Arch Pediatr Adolesc Med* 2007; 161: 1154–61.
 53. GORELICK MH, STEVENS MW, SCHULTZ T, SCRIBANO PV. Difficulty in obtaining peak expiratory flow measurements in children with acute asthma. *Pediatr Emerg Care* 2004; 20: 22–6.
 54. POLLACK CV, POLLACK ES, BAREN JM, et al. A prospective multicenter study of patient factors associated with hospital admission from the emergency department among children with acute asthma. *Pediatr Adolesc Med* 2002; 156: 934–40.

Appendix

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