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Gender differences in the association of overweight and asthma morbidity among urban adolescents with asthma

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Abstract

Asthma and obesity disproportionately affect US African-American youth. Among youth with asthma, obesity has been associated with poor control. The impact of gender on this association is unclear. We examined these relationships in a sample of urban, African-American adolescents with asthma. Questionnaires were used to identify high school students with asthma, and to examine the association of body mass index (BMI) to asthma morbidity, by gender. Of 5967 students completing questionnaires, 599 (10%) met criteria for asthma and 507 had data sufficient for inclusion in further analyses (46% male, mean age = 15.1 yr). Univariately, BMI > 85th percentile was significantly related only to reported emergency department visits (ED) and school days missed for any reason, Odds Ratio (95% Confidence Interval) = 1.7(1.1–2.7), $p = 0.01$ and 1.8(1.1–3.0), $p = 0.01$, respectively. A significant gender-BMI interaction ($p < 0.05$) was observed in multivariate models for ED visits, hospitalizations and school days missed for asthma. In gender-specific models, adjusted Risk Ratios for BMI > 85th and ED visits, hospitalizations, and school days missed because of asthma were 1.7(0.9–3.2), 6.6(3.1–14.6) and 3.6(1.8–7.2) in males. These associations were not observed in females. Gender modifies the association between BMI and asthma-related morbidity among adolescents with asthma. Results have implications for clinical management as well as future research.

Keywords

asthma; obesity; adolescents; African-American; gender

Both asthma and obesity represent public health challenges for urban communities (1, 2). Racial and ethnic disparities in asthma morbidity and mortality persist, despite reports of an overall decrease in US rates (1, 2). Over a similar time period, obesity has more than

doubled among all US residents, but prevalence remains highest among African-American and Latino females (2).

An association between obesity and asthma incidence and prevalence has become evident through longitudinal and cross-sectional studies, but obesity may also be important in disease management for persons with asthma. Several studies have shown that, among persons with asthma, severity and poor asthma control are related to overweight status (3, 4).

Although there are reports of gender differences in the relationship of obesity to asthma in study populations not restricted to persons with asthma, there is no consensus on which gender confers a higher risk (5). A limitation cited for a number of these studies is the lack of a statistical evaluation of an interaction between gender and obesity (5). The affect of gender on the relationship between obesity and poor asthma control among persons with asthma has not been well studied. Exploration of the obesity-asthma relationship among persons with asthma can provide information useful in the clinical management of asthma and can inform future research.

We examined the associations between gender, obesity and asthma morbidity in urban teenagers with asthma. Asthma death rates for US African-American teenagers are higher than that of younger age groups (6). Overweight in adolescence tends to extend into adulthood and asthma persisting through adolescence is associated with increased severity and higher morbidity compared to asthma that subsides during childhood (7). Results of previous studies suggest that the impact of gender on the obesity-asthma relationship may differ by age (8, 9). For these reasons, adolescence represents a critical age for aggressive intervention in the management of both weight and asthma.

We used data from a self-administered questionnaire given to urban, high school students to explore the association of body mass index (BMI) to self-report of asthma morbidity and control. This analysis differs from previous cross-sectional analyses in that it focuses on urban adolescents aged 15–18 yr and evaluates a possible interaction between gender and BMI in this age group.

Methods

This study was approved by the Henry Ford Health System Institutional Review Board and the appropriate school district offices. Detailed methods of this study have been described previously (10). Briefly, caregivers of all 9th–11th graders of six Detroit public high schools were notified by mail of a respiratory health survey to be administered during a regularly scheduled English class in October of 2003. The notification letter was signed by the principal of the participating school. Caregivers could refuse to have their student participate by signing and returning the letter to the school. To maintain student confidentiality, mailings were conducted by an authorized District vendor. The questionnaire used items from nationally recognized instruments and requested information on demographics, height and weight, asthma diagnosis and the occurrence of respiratory symptoms. Students were also asked about health care utilization for symptoms, school days missed for any reason and school days missed for asthma (11).

Current asthma was defined as report of a physician diagnosis of asthma, use of prescribed asthma medication in the last 12 months and at least one episode of wheeze in the last 12 months (12). Classification of asthma severity was accomplished using Expert Panel II Guidelines for Diagnosis and Treatment of Asthma (11). As done in previous studies, investigators interpreted and assigned numeric values when terms such as 'frequent' and 'continual' were used in the Expert Panel II criteria (13). Uncontrolled asthma was defined as inhaler use ≥ 2 times/week, nighttime symptoms ≥ 2 nights in last 30 days and ≥ 2 inhaler refills in last year [Rules of Two^{TM}, Baylor University]. BMI was calculated as kilograms/height in meters². Percentile ranges used in this paper correspond directly to those weight status categories recommended by the Department of Health and Human Services, Centers for Disease Control for youth, i.e., underweight = < 5th percentile, healthy weight = 5th to < 85th percentile, at risk of overweight = 85th to < 95th percentile and overweight = ≥ 95 th percentile (14). Percentiles were determined separately for males and females.

Statistical analysis

Confidence intervals for proportions were calculated using the asymptotic Gaussian method (15). For bivariate analyses, a Wilcoxon rank sum test was used to compare distributions for continuous variables and a Chi Squared test was used for comparisons involving categorical variables (15). Multivariable analyses were conducted to evaluate the independent association of BMI ≥ 85 th percentile to morbidity. Separate models were run for Emergency Department (ED) visits, hospitalizations, school days missed for any reason, school days missed for asthma and uncontrolled asthma. Logistic regression was used to calculate odds ratios and corresponding 95% confidence intervals for binary variables. Negative binomial regression was used to calculate risk ratios (RR) and corresponding 95% confidence intervals for count variables. An interaction term for BMI and gender was tested in each model. All calculations were performed using SAS 9.1 TS Level 1M2, Windows Version 5.2.3790.

Results

A total of 7446 9th–11th grade students were assigned to an English class in the six participating high schools in October, 2003 (Fig. 1). Less than 0.1% of parents refused to have their student complete the questionnaire. Forms for 5967 students (80%) were returned from 143 of 153 English teachers (93%). Of the 10 non-participating teachers, eight were specialists in alternative curricula (special education) and accounted for an estimated 334 (22.6%) of the 1479 unreturned forms.

Description of the study sample

Of the 5967 students, 52% qualified for federal school lunch programs and 98.6% were African-American. Of these, 599 students, or 10% (9.3%–10.3%), met criteria for asthma, forming our population base for analysis (Fig. 1). Ninety-two students (15.4%) were excluded from further analysis because of missing weight, ($n = 71$ or 11.9%), or incorrectly completed questions on height or weight ($n = 21$ or 3.5%). Table 1 is a comparison of these groups. Students who did not report weight were more likely to be smokers ($p = 0.03$). Students with unusable height or weight information did not differ significantly from those

providing this information (Table 1). Of the remaining 507 students, 108 (21.3%) had BMI > 85th. Table 2 shows the association of student characteristics to reports of asthma morbidity. As shown, 42.0% (213/507) made 1 ED visit, 13.4% (68/507) reported 1 hospitalization, 64.9% (329/507) missed 1 school days in the past 30 days for any reason and 34.5% (175/507) 1 school days in the past 30 days due to asthma. BMI > 85th was significantly related to ED visits and missed school for any reason. (Table 2).

BMI, smoking and gender

As smoking and gender were related to morbidity, we examined these variables in relation to BMI > 85th (data not shown). There were more smokers among students with BMI > 85th (29.0% smokers with BMI > 85th vs. 20.8% non-smokers), OR = 1.6 (0.7, 3.5), $p = 0.30$ and fewer smokers were male (5.1% male smokers vs. 6.9% female), OR = 0.7 (0.4, 1.5), $p = 0.40$. Mean BMI for males was 24.5 (s.d. = 6.1) and 25.3 (s.d. = 6.1) for females. Male gender was not related to BMI > 85th (22.3% males with BMI > 85th vs. 20.4% females), OR = 1.1 (0.7, 1.7), $p = 0.61$.

BMI, asthma severity and uncontrolled asthma

Logistic regression was used to examine the association of BMI > 85th percentile to asthma severity and to uncontrolled asthma (data not shown). Asthma severity was not significantly associated with BMI > 85th percentile after adjusting for potential confounders. ORs for the association of BMI > 85th to increasing asthma severity (using mild, intermittent as reference group for categories mild, persistent, moderate and severe persistent) ranged from 1.2–1.4; with all confidence intervals including 1.0 (data not shown).

Uncontrolled asthma, defined as at least one of the following: inhaler use 2 times/week, nighttime symptoms > 2 nights in last month, or 2 rescue inhaler refills per year, was not related to BMI > 85th, OR = 0.8 (0.4–1.5). Variables making up the study definition for uncontrolled asthma were not individually related to BMI > 85th with adjusted ORs ranging from 0.9 and 1.1 and all confidence intervals including 1 (data not shown).

BMI > 85th and school days missed

To examine whether school days missed due to asthma and school days missed for any reason were independently related to BMI > 85th, we created a new variable, school days missed due to reasons other than asthma, by subtracting the school days missed due to asthma from school days missed for any reason (data not shown). Both variables were then entered into a regression model with BMI > 85th as the dependent variable and with age, asthma severity, gender, income, smoking and Environmental tobacco smoke (ETS) as covariates. The adjusted ORs for school days missed due to asthma and for school days missed due to reasons other than asthma were 1.5 (0.8–2.8), $p = 0.23$ and 2.1 (1.2–3.8), $p = 0.01$, respectively.

BMI-gender interaction

In multivariate analyses, a significant interaction was observed for BMI > 85th and gender in the model for ED visits ($p = 0.05$), hospitalization ($p = 0.02$) and for school days missed due to asthma ($p = 0.04$), but not school days missed for any reason ($p = 0.25$). Results of

regression analyses are presented separately for males and females in Table 3. Among females, BMI > 85th percentile was not significantly related to asthma morbidity. For males, aRR for BMI > 85th and morbidity were significantly elevated for hospitalizations and school days missed due to asthma and were of borderline significance for ED visits and school missed for any reason.

Discussion

In our study of African-American teenagers with asthma, BMI > 85th was associated with increased reports of asthma-related morbidity when compared to that of students with healthier weights, but this association was evident only for males. We also noted in our study that overweight students with asthma miss more school than those with BMI ≤ 85th. This is similar to earlier reports in which severely obese students missed a mean of 4.2 school days (s.d. = 7.7) in a 30-day period compared to 0.7 days (s.d. = 1.7) for children of normal weight (16). In our study, school absenteeism for reasons other than asthma and absenteeism due to asthma were independently related to BMI > 85th. Drop out rates for these students may also be higher, although we have no data to support this hypothesis.

We know of two cross-sectional US studies conducted among individuals with asthma that have shown a relationship between asthma prevalence, or asthma severity and increased weight. Belamarich [2000] found that overweight was related to steroid use, symptom-days and ED visits among urban children aged 4–9 yr with asthma (4). Luder et al., reported an association between BMI > 85th and absenteeism, peak flow and number of asthma medications prescribed among African-American and Hispanic children with asthma, aged 2–18 yr (3).

To our knowledge, this paper is the first US cross-sectional study to report a statistical interaction between gender and BMI with regards to asthma morbidity in urban, African-American adolescents aged 15–18 yr with asthma; therefore we cannot compare our results to that of previous studies. In reviewing studies of obesity and asthma among persons with and without asthma, we found 8 prior US studies on this topic that did not explore gender differences (3, 4, 17–22). Although three included 17–18 yr olds (3, 17, 18) all eight studies included children ≤ 12 yr. One additional study by von Mutius et al., found a significant positive association between BMI and asthma, but no effect modification by gender was observed (23). Of nine non-US studies among youth that investigated increased weight and asthma, six did not test for a gender-obesity interaction (24–29); and two reported that the association of BMI to asthma was stronger for boys (24, 25). Results varied in the three studies that did test for an interaction (8, 30, 31) and although one study reported adjusted ORs for the association of overweight and current wheeze of 2.4 and 1.6 for boys and girls respectively, the interaction term was not significant (30). Because these studies were not done in populations restricted to asthma, comparisons to our results are limited. Taken together, previous and current reports do indicate the need for further study in this area.

Alternative explanations for our results are possible. Adolescents with severe asthma are less active, and may be heavier than adolescents with milder asthma. In our study, however, BMI was not related to severity classifications, although severity was significantly related to

morbidity. Possibly overweight youth report more symptoms, but BMI > 85th, in this study, was not related to uncontrolled asthma or symptom frequency. We did not have information on physical activity for our study sample; however, it is unlikely that physical activity influenced our results. Males may be more physically active and consequently have more opportunity to experience symptoms, but if increased physical activity among males resulted in a lower BMI, we would not expect the results we observed (high BMI related to more asthma morbidity). On the other hand, increased muscle mass among male athletes may result in more males having a BMI > 85th and consequently, the observed association between BMI > 85th and morbidity. The ability of BMI to accurately reflect adiposity for athletic adults is reportedly lower than that of non-athletic adults, but this has not been reported in children or adolescents, let alone those with asthma. Instead, among children in national samples, high BMI is considered a moderately sensitive and very specific indicator of excess adiposity (32, 33). We acknowledge that our findings may be due to variables we did not collect in our study, or due to factors for which we could not control in our analyses.

The prevalence of current asthma in this population was approximately 10%. Comparison across studies is difficult due to the lack of standardization for case-definitions of asthma and the lack of published information on asthma in urban, high school students. According to the Michigan Department of Community Health, the prevalence of current asthma in Michigan is 9.1% for children less than 18 yr (34, 35). Several studies in the literature report asthma prevalence for middle and high school African American students with estimates ranging from 8.7% to 16.8% for African-Americans (36–38).

Limitations of our study include an inability to calculate BMI for about 15% of our study sample, although differences in asthma morbidity were not observed between the groups with and without height/weight data. The exclusion of these students alters the true distribution of BMI in our study population, resulting in an over- or underestimate of the true association between BMI > 85th and asthma morbidity. A second limitation is that data is based on self-report. Despite encouraging results from a recent study showing a high correlation between self-reported and measured BMI values for adults > 20 yr (39) and that several sentinel health studies have been based on self-report data, (e.g., National Health Interview Survey), our results should be confirmed in larger, longitudinal studies involving primary data collection on weight, height and asthma-related morbidity. Third, we were unable to examine the relationship of asthma morbidity and BMI by medication use, allergic status, family history of asthma, or as mentioned above, physical activity. Finally, the demographics of our study population in terms of age, race and socioeconomic status may limit the generalizability of our findings.

Our analysis focuses on morbidity in a sample of individuals identified as having asthma, but factors related to obesity and increased risk of asthma could also be important in asthma control. Obesity and asthma could be linked through several pathways, including alterations in airway mechanics, environmental factors such as diet and a shared genetic susceptibility in that similar candidate gene and gene regions for obesity have also been associated with asthma and asthma phenotypes (40). Differences by gender have led some researchers to suggest hormonal pathways, i.e., increases in estrogen and concomitant decreases in

progesterone, resulting in a reduction of β_2 adrenoreceptor density and bronchial smooth muscle relaxation.

Immunologic pathways may also explain the obesity-asthma relationship. The inflammatory cytokine, leptin, has been associated with airway hyperresponsiveness and Th2 cytokine production – both important asthma phenotypes. However, among adults, it has been hypothesized that the obesity-asthma relationship is less due to atopy and more due to $\text{INF}\gamma$ -induced T-cell mediated mechanisms (41). This has been proffered as an explanation for a stronger asthma-obesity relationship observed in non-atopic asthma patients compared to atopic asthma patients (41). Results of another study conducted among persons with asthma suggested that greater production of $\text{INF}\gamma$ and increased corticosteroid refractoriness among adults with chronic asthma was potentially responsible for a lowered response by obese patients to inhaled steroids, resulting in asthma that is less easily managed in overweight persons (42). This hypothesis is in accord with our findings in that severity did not modify the relationship between BMI and morbidity, suggesting that high BMI is associated with exacerbations that are less responsive to certain treatments and take longer to resolve.

The contribution of overweight and obesity to asthma control is of interest to clinicians as well as researchers, especially given the disproportionate prevalence of both conditions in urban communities. Just as with asthma incidence and prevalence, mechanisms underlying poorer disease control among overweight persons with asthma may be influenced by age and gender. Moreover, at least one US study in adults suggests that the complex interplay between asthma, gender and obesity may differ by race (43). Association studies, such as the one described here, are hypothesis-generating, clinically-relevant and provide a backdrop for researchers evaluating potential biologic mechanisms for the obesity-asthma relationship.

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Fig. 1.

Results of respiratory questionnaire administered to students in grades 9–11, fall 2003.

*Current asthma was defined as report of the following: a physician diagnosis of asthma, use of prescribed asthma medications in the last 12 months, and at least one episode of wheeze in the last 12 months.

Table 1

Characteristics of study sample and comparison of students by information provided (among those meeting study criteria for asthma)

	a Reported height, weight (n = 507)		b Did not report weight (n = 71)		c Data on height and/or weight unusable (n = 21)		p (a vs. b)	p (a vs. c)
Mean (s.d.) age	15.1 (1.0)		15.4 (1.1)		15.5 (0.8)		0.12	0.07
Mean (s.d.) Income/person *	12142 (2433)		12086 (2567)		12123 (2532)		0.99	0.72
n (%) female	274 (54.0)		37 (52.1)		11 (52.4)		0.76	0.88
n (%) smoker **	31 (6.1)		10 (14.1)		1 (4.8)		0.03	0.99
n (%) ETS [†]	299 (59.0)		44 (62.0)		13 (61.9)		0.63	0.79
Mean (s.d.) ED visits/12 months	2.4 (6.9)	0–2	3.3 (10.5)	0–2	1.1 (2.4)	0–1	0.59	0.27
Mean (s.d.) Hospitalization/12 months	1.2 (6.4)	0–0	1.5 (5.0)	0–0	2.9 (12.0)	0–0	0.14	0.68
Mean (s.d.) school days missed/30 days	4.1 (6.7)	0–5	4.0 (7.2)	0–4	6.3 (8.5)	0–9	0.59	0.31
Mean (s.d.) school days missed (asthma)	1.9 (4.9)	0–1	2.1 (5.6)	0–1	2.4 (7.6)	0–0	0.30	0.24

* Median household income divided by the average household size for the zip code or census tract of residence.

** Smoked > 2 cigarettes on the days smoked in the last 30 days⁴⁵.

[†] Exposed to environmental tobacco smoke at home.

IQR = Interquartile range. Ranges for emergency department visits (ED) visits col a, b, c, respectively: 0–90, 0–71, 0–10; for hospitalization: 0–90, 0–34, 0–55; for school days missed/30 days: 0–30, 0–30, 0–30; for school days missed (asthma): 0–30, 0–30, 0–30.

Table 2

Association of student characteristics to emergency department visits, hospitalizations, and school days missed for asthma* (n = 507)

	1 ED visit		No. ED visits		OR (95%CI)**		1 Hosp.		No. Hosp.		OR (95%CI)		p	
	1 sch. day missed	No. sch. day missed	1 sch. day missed	No. sch. day missed	OR (95%CI)**	p	1 sch. day missed	No. sch. day missed	OR (95%CI)	p				
Age, mean (s.d.)	15.1 (0.9)	15.1 (1.1)			0.86		15.1 (0.9)	15.1 (1.0)			0.68			
Income, mean (s.d.)	11934 (2511)	12293 (2368)			0.13		11585 (2553)	12229 (2406)			0.06			
BMI > 85th, n (%)														
Yes	57 (52.8)	51 (47.2)			1.7 (1.1, 2.7)	0.01	19 (17.6)	89 (82.4)			1.5 (0.9, 2.7)	0.15		
No	156 (39.1)	243 (60.9)					49 (12.3)	350 (87.7)						
Gender, n (%)														
Male	82 (35.2)	151 (64.8)			0.6 (0.4, 0.8)	0.004	34 (14.6)	199 (85.4)			1.2 (0.7, 2.0)	0.47		
Female	131 (47.8)	143 (52.2)					34 (12.4)	240 (87.6)						
Smoker [†] , n (%)														
Yes	15 (48.4)	16 (51.6)			1.3 (0.6, 2.7)	0.46	12 (38.7)	19 (61.3)			4.7 (2.2, 10.3)	< 0.001		
No	198 (41.6)	278 (58.4)					56 (11.8)	420 (88.2)						
ETS [‡] , n (%)														
Yes	126 (42.1)	173 (57.9)			1.0 (0.7, 1.5)	0.94	39 (13.0)	260 (87.0)			0.9 (0.6, 1.6)	0.77		
No	87 (41.8)	121 (58.2)					29 (13.9)	179 (86.1)						
Severity [§] , n (%)														
Intermittent	94 (31.3)	206 (68.7)			1.0		23 (7.7)	277 (92.3)			1.0			
Persistent	36 (47.4)	40 (52.6)			2.0 (1.2, 3.3)	0.009	18 (23.7)	58 (76.3)			3.7 (1.9, 7.4)	< 0.001		
Moderate	30 (56.6)	23 (43.4)			2.9 (1.6, 5.2)	0.001	10 (18.9)	43 (81.1)			2.8 (1.2, 6.3)	0.013		
Severe	49 (72.1)	19 (27.9)			5.7 (3.2, 10.1)	< 0.001	17 (25.0)	51 (75.0)			4.0 (2.0, 8.0)	< 0.001		
Asthma														
Any reason														
Age, mean (s.d.)	15.2 (1.0)	15.0 (1.0)			15.0 (1.0)	0.03		15.2 (1.0)			15.1 (1.0)		0.16	
Income, mean (s.d.)	12181 (2500)	12071 (2311)			12312 (2345)	0.67		11821 (2568)			12312 (2345)		0.03	
BMI > 85th, n (%)														
Yes	81 (75.0)	27 (25.0)			1.8 (1.1, 3.0)	0.01		39 (36.1)			69 (63.9)		1.1 (0.7, 1.7)	
No	248 (62.2)	151 (37.8)						136 (34.1)			263 (65.9)		0.69	
Gender, n (%)														

	Any reason				Asthma			
	1 sch. day missed	No. sch. day missed	OR (95%CI)**	p	1 sch. day missed	No. sch. day missed	OR (95%CI)**	p
Male	134 (57.5)	99 (42.5)	0.5 (0.4,0.8)	0.001	70 (30.0)	163 (70.0)	0.7 (0.5, 1.0)	0.05
Female	195 (71.2)	79 (28.8)			105 (38.3)	169 (61.7)		
Smoker [†] , n (%)								
Yes	26 (83.9)	5 (16.1)	3.0 (1.1,7.9)	0.03	14 (45.2)	17 (54.8)	1.6 (0.8, 3.4)	0.20
No	303 (63.7)	173 (36.3)			161 (33.8)	315 (66.2)		
ETS [‡] , n (%)								
Yes	200 (66.9)	99 (33.1)	1.2 (0.9,1.8)	0.26	104 (34.8)	195 (65.2)	1.0 (0.7, 1.5)	0.88
No	129 (62.0)	79 (38.0)			71 (34.1)	137 (65.9)		
Severity [§] , n (%)								
Intermittent	179 (59.7)	121 (40.3)	1.0		71 (23.7)	229 (76.3)		
Persistent	53 (69.7)	23 (30.3)	1.6 (0.9,2.7)	0.10	34 (44.7)	42 (55.3)	2.6 (1.5, 4.4)	<0.001
Moderate	46 (86.8)	7 (13.2)	4.4 (1.9,10.2)	<0.001	32 (60.4)	21 (39.6)	4.9 (2.7, 9.1)	<0.001
Severe	47 (69.1)	21 (30.9)	1.5 (0.9,2.7)	0.15	35 (51.5)	33 (48.5)	3.4 (2.0, 5.9)	<0.001

* Students with missing data for school days missed for asthma or any reason included in the denominator for these outcomes.

** Odds ratio and 95% confidence interval.

[†] Environmental tobacco smoke (ETS) defined as smoked 2 or more cigarettes in days smoked in last 30 days⁴⁵.

[‡] At least 1 adult smoker in the home where student resides.

[§] Categories are mild intermittent (Intermittent), mild persistent (Persistent), moderate persistent (Moderate), and severe persistent (Severe).

Table 3

Multivariable analysis for the association of BMI > 85th percentile and report of asthma morbidity, stratified by gender* (n = 507)

Dependent variable	Adjusted risk ratio [†]	(95% CI)	p
Female			
ED visit	1.0	(0.6–1.7)	0.92
Hospitalization	0.9	(0.4–1.9)	0.75
Missed school	1.1	(0.7–1.6)	0.74
Missed school due to asthma	0.9	(0.5, 1.5)	0.60
Male			
ED visit	1.7	(0.9–3.2)	0.06
Hospitalization	6.6	(3.1–14.6)	< 0.001
Missed school	1.7	(0.96–3.0)	0.07
Missed school due to asthma	3.6	(1.8–7.2)	< 0.001

* Test of BMI > 85th-gender interaction for emergency department visits (ED) model p = 0.05, for hospitalization model; p = 0.02, for school days missed model p = 0.25, for school days missed due to asthma model p = 0.03.

[†] Adjusted for age, smoking, income/person, ETS and severity.