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Comparison of Anthropometric Measures of Obesity in Childhood Allergic Asthma: Central Obesity is Most Relevant

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Abstract

Background—Established indicators of central obesity include waist circumference, waist to height ratio and the conicity index. Studies utilizing such measures (as opposed to body mass index (BMI) percentiles) to characterize the association between obesity and asthma are lacking despite the fact that these measures have been shown to be most relevant for many other chronic diseases.

Objectives—To examine measures assessing the distribution of obesity in the context of childhood allergic rhinitis and asthma, and to elucidate the association of obesity, including central obesity, with allergic asthma in children.

Methods—Children with allergic rhinitis with (cases) or without (controls) asthma were recruited. BMI percentiles were derived using national growth charts. Waist circumference, waist to height ratio, and conicity index were obtained.

Results—Central obesity was associated with asthma, asthma severity, lower lung function, and reduced atopy in asthmatics.

Conclusion—Measures of central obesity are more associated with the presence of asthma and asthma severity in children with allergic rhinitis when compared to standard BMI measures.

Clinical Implication—Current practices of measuring weight and height in pediatric clinics that treat children with allergic rhinitis should include waist circumference measurements to better assess obesity and asthma risk.

Keywords

Asthma; Obesity; Children; BMI percentiles; Waist circumference

Introduction

Obesity is a major public health problem that often begins in childhood and is increasing at an alarming rate[1]. Obesity affects multiple target organs and is associated with other diseases,

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Capsule summary: Measures of central obesity, including waist to height ratio and conicity index, may improve the evaluation of asthma susceptibility and severity in children with allergic rhinitis when compared to standard BMI measures.

including asthma[2]. The parallel rise in the prevalence of asthma and obesity suggests that these disorders may be linked[3, 4]. Compared with non-asthmatics, BMI in adults with asthma is 44–48% higher across three cross-sectional US health surveys[5]. Further support for an association between asthma and obesity is provided by prospective studies, which show that risk for asthma increases with increasing BMI[6–9]. Indeed, a recent meta-analysis confirmed that obesity is a strong risk factor for incident asthma[10]; risk for asthma increased from being overweight to obese in a dose-response fashion[10]. Notably, as obese asthmatics lose weight, their asthma symptoms and lung function improve[11].

While the above studies are performed in adults, childhood studies that investigate the relationship between asthma and obesity are few and contradictory[12–16]. Several studies report increased prevalence of obesity in asthmatics[5, 8, 17], while others fail to find such a relationship[18–20]. Inconsistent findings may result in part from the inadequate classification of obesity phenotypes.

One of the most widely used tools to screen for obesity is BMI. However, BMI is an indicator of relative body weight that may not adequately reflect fat distribution[21], and may underestimate or overestimate obesity in children since wide variations in body fat may occur within the same BMI percentile group[22]. Also, children undergo complex growth-related shifts in fat distribution independent of BMI[23]. Thus, individuals classified as obese using BMI may not be classified as obese using more direct measures of body fat. There is strong agreement that health risks for obesity are most associated with fat distribution rather than body weight[24]. Thus, alternative measures that are more reflective of fat distribution may better identify obese children at increased risk for asthma[22].

Alternative measures that account for fat distribution include waist circumference, a measure of abdominal (central) obesity that, compared to BMI percentiles, better predicts risk for some diseases such as cardiovascular disease[25]. Similarly, waist to height ratio[26] and conicity index[27, 28] have been found to be more sensitive than BMI in predicting risk for cardiovascular disease. To date, these measures are rarely used in childhood studies and even less frequently used to assess obesity in childhood asthma. This study was conducted to compare these alternative measures with BMI percentiles in order to determine how they differ in their classification of obesity and in their association with asthma severity in children with allergic rhinitis.

Methods

Subjects

Children ages 5–18 years were sequentially recruited from the outpatient Allergy/Immunology clinics at Cincinnati Children's Hospital Medical Center (CCHMC), N=1123. Exclusion criteria included: 1) co-morbid lung condition; 2) chronic disease other than allergic disorders; and 3) dependency on an immunosuppressive agent for a medical condition other than asthma. Detailed questionnaires to collect medical information were completed by the parent/guardian accompanying the child during the clinic visit[29–31]. Height(m), weight(kg), and waist circumference(cm) were measured during the clinic visit by a trained professional[32]. Of the 1123 children, 482 children had a waist circumference measurement. There were no significant differences in race, age, or annual household income between children without a waist circumference measurement and those with a waist circumference measurement. There was a borderline difference in gender among children without a waist circumference measurement (46.6% female) compared with those with a measurement (41% female) (p=0.05).

Outcome definitions

Pulmonary function testing was performed and asthma was diagnosed according to the American Thoracic Society guidelines [33]. Asthma severity was designated based on lung function (FEV_1) and frequency of symptoms, and was classified into mild, moderate or severe[31].

Allergy skin prick testing (SPT)

Allergic sensitization was determined in all subjects by SPTs to eleven aeroallergens (mold mixes (2), grass mix, ragweed (giant and short), tree pollen mixes (2), weed mix, dust mite mix, cat, dog, and cockroach mix) common to the Ohio River Valley (Hollister-Stier). Skin prick testing was performed using GREERPick™ (Greer Laboratories, Lenoir, North Carolina). Sensitization was defined as present when there was wheal greater than 3 mm and greater than the saline negative control. Histatrol® (Center Laboratories, Port Washington, NY) was used as the positive control. A child was considered to have allergic rhinitis if they had rhinitis as well as a positive SPT to at least one aeroallergen. The study was approved by the CCHMC IRB.

Obesity Measures

BMI was calculated as weight(kg)/height^2(m^2) and was converted into age and gender specific BMI percentiles[34]. Conicity index was calculated as [waist circumference(m)/0.109*square root(weight(kg)/height(m)][28]. Waist to height ratio was calculated as waist circumference(cm)/height(cm). Spearman correlation coefficients (r) were used to examine the relationships between BMI percentiles and the other obesity measures. To facilitate the comparison of the obesity measures, the alternative measures were standardized by subtracting the mean and dividing by the standard deviation. All the measures were categorized into three groups based on the 25th and 85th percentile. Participants who were ≤25th percentile of the obesity measure were assigned to the normal, >25th–<85th percentile to the intermediate, and ≥85th percentile to the high weight stratum. Since the 95th percentile gave similar trends to the 85th percentile, the 85th percentile was used as the cutoff for the high weight stratum to allow sufficient analytic power. The 85th percentile is a reasonable cutoff as previous studies have demonstrated that the 85th percentile for BMI provided a sensitivity of 67% in males and 75% in females for total body fat screening[35].

Statistical Analysis

When no association was seen between the obesity measures with having asthma in the whole population (n=1123), the analytic population was restricted to children with allergic rhinitis (n=584). Allergic rhinitis was chosen as the control group because a large proportion of asthmatics were skin test positive with allergic rhinitis. Among children with allergic rhinitis, the effect of the obesity measures on the probability of mild asthma vs. no asthma and moderate/severe asthma vs. no asthma was tested. Since the model parameters and odds ratios were similar using both outcomes, the outcome was combined into one three-level asthma severity variable (no asthma, mild asthma, moderate/severe asthma). Generalized logistic regression models were used to investigate the relationship of the obesity measures with asthma severity in children with allergic rhinitis. Logistic regression was used to investigate the relationship between the obesity measures and the likelihood of having at least one positive SPT versus a negative SPT. Skin prick test results were also converted into an atopy index (0, negative to all aeroallergens; 1, positive to 1–2 aeroallergens; 2, positive to 3–4 aeroallergens; or 3, positive to ≥5 aeroallergens) in order to examine the effect of obesity on an incremental increase in allergic sensitization. Proportional odds regression was used to determine the association between each obesity measure and the atopy index. The models were tested in the whole population and then stratified by diagnosis (asthma vs. no asthma).

Continuous variables were logarithmically transformed if needed to achieve normality. In all models, potential covariates considered include race, age group, gender, maternal and paternal education, smoking in the household, and annual household income. Comparisons of categorical data were performed using the chi square test or Fisher's exact test. The Wilcoxon two-sample test with t-approximation was used to compare continuous data that was not normally distributed. A two-tailed p value ≤ 0.05 was considered statistically significant.

Percentile Curves for Obesity Measures

Percentile curves were constructed for each obesity measure using quantile regression[36] for children with allergic rhinitis. Fitted values were computed for the 10th, 25th, 50th, 75th, 85th, 90th, and 95th percentiles. The resulting fitted values, together with the original raw data, were then plotted against age to create the percentile curves separately constructed by race (African American and Caucasian) and gender. BMI percentiles were constructed for Caucasian children ages 5–15 years. The curves for African Americans and for the remainder of the obesity measures were limited to 5–12 year old children due to the sparsity of the data outside this age range. Due to lack of adequate sample size, the 90th percentile of waist circumference for Caucasian girls, and the 95th percentile for the African American girls could not be accurately calculated. The percentile curves for (a) Caucasian boys, (b) Caucasian girls, (c) African American boys, and (d) African American girls are illustrated in Online Repository Figures 1–4 (BMI percentiles, waist circumference, waist to height ratio, and conicity index respectively). In addition, the 25th, 75th, 85th, and 95th percentile distributions of each obesity measure are presented by age and gender in Caucasians (Table Ia online repository) and African Americans (Table Ib, online repository). All the above analyses were conducted using SAS version 9.1.2 (SAS Institute, Cary, NC, USA).

Structural Equation Modeling

In order to account for the mediating effects of the obesity measures in the context of asthma and allergic sensitization, a structural equation model was developed using the M*plus* software [37]. This model was tested in the whole population (n=1123). A value for the [estimated coefficient/standard error of the estimate] ≥ 1.65 was considered statistically significant (equivalent to the 0.1 level). Further detail of the structural equation modeling is available in the on-line repository.

RESULTS

Characteristics of study subjects

The total study population consisted of 1123 children, ages 5–18 years, and just over half (n=584) of the children were diagnosed with allergic rhinitis (Table I). Of the children with allergic rhinitis, 54.79% had asthma (cases) and 45.21% did not have asthma (controls). No statistical differences in gender, parental education, household member smoking, or annual household income were found between the cases and controls. There were significantly more African Americans in the asthma group (43.13%) versus the control group (34.09%) ($p<0.05$). Cases were older than the controls, with 60.31% of the cases being 9.5 years and older, compared to 47.73% of the controls ($p<0.05$). No differences were found in the median and interquartile ranges of the obesity measures between allergic rhinitis children with or without asthma (not shown).

BMI percentiles classify 17–46% of obese children differently than the central obesity measures

BMI percentiles showed the strongest correlation with waist to height ratio (r= 0.73) and waist circumference (r=0.59); and the lowest correlation with conicity index (r=0.36). All correlations were statistically significant ($p < 0.005$) and did not differ by diagnosis (not shown). A comparison of the alternative measures with BMI percentiles using the chi square test is shown in Table II. Among individuals classified as obese using waist circumference, 1.43% were classified as normal weight and 37.14% as intermediate weight using BMI percentiles. Thus, a total of 38.57% (1.43% + 37.14%) of children designated as obese using waist circumference were classified as non-obese using BMI percentiles (discordant). Among those classified as obese using waist to height ratio, 17.19% were discordant using BMI percentiles; using conicity index, 46.27% were discordant using BMI percentiles. All comparisons were significant at the 0.0001 level. Thus, BMI percentiles may classify up to 46% of children differently than the other measures in terms of obesity.

Prevalence of moderate/severe asthma is higher in centrally obese children with allergic rhinitis

Generalized logistic regression models with the cumulative logit function were used to determine the effect of each obesity measure on the likelihood of having asthma compared with no asthma among children with allergic rhinitis. The models were adjusted for age and race. Gender did not differ between the groups, but it was still included in the models. As shown in Table III, the proportion of children with moderate/severe asthma was significantly higher among children who were in the high conicity index stratum (≥85%). This trend reached significance only with the measure of conicity index, but trended toward significant for the other measures of central obesity. Across conicity index strata, the proportion of children with moderate/severe asthma steadily increased from 28.57% to 36.88% to 43.75% ($p<0.01$). Children classified as obese using the conicity index were approximately 2.6 times more likely to have asthma (OR=2.63, 95% CI=1.19–5.82) ($p<0.05$). These trends were maintained in Caucasians. The associations could not be assessed in African Americans due to the limited sample size.

The effect of each obesity measure on FEV_1 was examined. (Table IV). BMI percentiles were significantly associated with FEV_1 both in children with (β coefficient=0.24) and without (β coefficient=0.53) allergic rhinitis, albeit more strongly in those without allergic rhinitis ($p<0.01$). Waist circumference was associated with a lower mean FEV_1 ($p<0.05$). The obesity measures explained 8% - 24% of the variance in the FEV_1 in children with allergic rhinitis, and 2% - 31% of the variance in children without allergic rhinitis. Notably, in children without allergic rhinitis, BMI percentiles explained the most variance in FEV_1 ($R^2=0.31$) while the conicity index explained the least ($R^2=0.02$). In contrast, in children with allergic rhinitis, waist to height ratio explained the most variance in FEV_1 ($R^2=0.24$) while BMI percentiles explained the least ($R^2=0.08$).

Association of obesity with the prevalence of allergic sensitization

Logistic regression was used to investigate the relationship between the obesity measures and the likelihood of having at least one positive SPT versus a negative SPT in the total population stratified by asthma diagnosis (Table V). The proportional odds model was also used to obtain ORs for the association of each obesity measure with the atopy index. Among the potential covariates, age and gender were significantly associated with the atopy index, thus age and gender were included in the multivariable regression models, in addition to parental education. The presence of obesity was inversely correlated with an increasing atopy index among children with asthma for both BMI percentiles (OR=0.49, 95% CI=0.27–0.90) and waist circumference (OR=0.38, 95% CI=0.14–1.01) ($p<0.05$).

The structural equation model confirms the association of central obesity with asthma

A structural equation model was utilized to assess the mediating effects of the obesity measures on asthma in the total population. The obesity measures were sequentially removed using backward elimination, starting with BMI percentiles. After removing BMI percentiles, the model fit improved significantly and no further elimination steps were needed. Figure 5 (Online Repository) displays the full structural equation model with the significant predictors and pathways shown in bold. Asthma was significantly associated with the measures of central obesity (Table VI). For each unit increase in waist circumference, the OR for asthma was significantly increased by about 3-fold (OR=2.95). Similarly, waist to height ratio in boys was positively associated with asthma (OR=2.43). In girls, conicity index was negatively associated with asthma (OR=0.43). None of the obesity measures were associated with the atopy index (data not shown).

DISCUSSION

Central obesity is the most critical determinant of obesity-related morbidity in many diseases. However, studies directly comparing obesity measures that assess central obesity with BMI measures are lacking in childhood asthma and allergic rhinitis. We directly compared obesity measures in children with allergic rhinitis with or without asthma. Our results demonstrate that measures that account for fat distribution and central obesity classify obesity differently than BMI. In fact, there was up to 46% discordance between BMI percentiles and the central obesity measures. Thus, a significant proportion of children with allergic rhinitis designated as obese or non-obese using BMI percentiles will be designated differently using alternative measures that account for central obesity. Furthermore, we observed a significant association of central obesity (assessed using conicity index) with having asthma and with more severe asthma. Although BMI percentiles were associated with asthma and asthma severity in Caucasians, the associations of central obesity measures with asthma were more consistent (even in mixed populations and in Caucasians), suggesting that central obesity may be superior to BMI percentiles in assessing the likelihood for having asthma in children with allergic rhinitis.

In contrast to asthma severity, a negative association was observed between obesity and allergic sensitization among asthmatics. Thus, allergic sensitization was less common among the obese subgroup. This finding was more pronounced with central obesity (assessed using waist circumference), and is supported by a study that found that central obesity was associated with non-atopic asthma in adults[38]. This suggests that among obese children, there are factors that contribute to the development of asthma independent of allergic sensitization. This is an important and intriguing observation. Allergic sensitization still occurs in the context of obesity, but mechanisms other than allergic sensitization likely contribute to the link between obesity and asthma. The structural equation model further supported this observation, since none of the obesity measures were associated with atopy, despite the robust association of central obesity with asthma.

To date, the majority of the studies that support an association between asthma and obesity using measures that assess fat distribution have been performed in adults and have been mainly limited to Caucasians[7, 38–40]. The study herein has several advantages. First, it was performed in Caucasian and African American children. In addition, the racial and socioeconomic makeup of the children participating in this study is similar to the national census figures (year 2000 figures, www.censusscope.org). The only exception is a higher proportion of African Americans, which is not surprising since asthma disproportionately affects this subgroup. Second, weight and height were objectively measured. In previous studies that found an association between obesity with asthma, several used self-reported weight and height[41, 42], which is a potential source of error due to reporting bias. Third, the diagnosis of asthma was based on objective lung function criteria, while other studies have relied largely on self-reported asthma[18, 41, 43]. Fourth, percentile curves were constructed for each obesity measure, providing race and gender-specific quantile reference values for this specific population. Finally, a structural equation model, examining the indirect effects of the obesity measures, confirmed the association of central obesity with asthma in all the children.

This study is not generalizable to the US population because it was performed in a clinic sample of children. Although the relationship between asthma and obesity, and specifically central obesity, is supported by our findings, no conclusions about causality can be made due to the cross-sectional design. Potential confounders that may impact the association between asthma and obesity include gastro-esophageal reflux disease and sleep disordered breathing. Neither of these was assessed in this study. However, gastro-esophageal reflux disease did not have an effect on the association between asthma and obesity in a longitudinal study[49]. Similarly, sleep disordered breathing based on sleep apnea or habitual snoring did not alter the association between obesity and asthma[50].

Given the burden of childhood obesity, these results have public health relevance. Based on these data, measures of central obesity should be incorporated in pediatric and allergy/immunology practices in order to better identify patients with allergic rhinitis who may be at increased risk for asthma due to co-morbid obesity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

BMI, body mass index; FEV_1, forced expiratory volume in one second; SPT, skin prick test.

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Table I

Socio-demographic characteristics of all study participants

Parameter	Total population n=1123		All children with allergic rhinitis n=584		Group 1: Children with allergic rhinitis and asthma n=320		Group 2: Children with allergic rhinitis only (no asthma) n=264	
Diagnosis	n	(%)	n	(%)	n	(%)	n	(%)
Allergic rhinitis	584	(52.0)	584	(100.0)	320	(100.0)	264	(100.0)
Asthma	469	(41.76)	320	(54.79)	320	(100.0)	0	0
Age groups*								
5 – < 9.5 years	562	(50.04)	265	(45.38)	127	(39.69)	138	(52.27)
9.5 – ≤ 18 years	561	(49.96)	319	(54.62)	193	(60.31)	126	(47.73)
Race*								
Caucasian	645	(57.44)	300	(51.37)	157	(49.06)	143	(54.17)
African American	379	(33.75)	228	(39.04)	138	(43.13)	90	(34.09)
Other	99	(8.82)	56	(9.59)	25	(7.81)	31	(11.74)
Males	620	(55.21)	334	(57.19)	192	(60.0)	142	(53.79)
Father's education								
Less than high school	66	(5.88)	34	(5.82)	19	(5.94)	15	(5.68)
High school/some college	477	(42.48)	255	(43.66)	133	(41.56)	122	(46.21)
College or higher	250	(22.26)	113	(19.35)	62	(19.38)	51	(19.32)
Unknown	330	(29.38)	182	31.16	106	(33.12)	76	(28.79)
Mother's education								
Less than high school	49	(4.36)	24	(4.11)	13	(4.06)	11	(4.17)
High school/some college	585	(52.1)	309	(52.91)	171	(53.44)	138	(52.27)
College or higher	263	(23.42)	122	(20.89)	59	(18.44)	63	(23.86)
Unknown	226	(20.12)	129	22.09	77	(24.06)	52	(19.69)
Annual household income								
< $10,000	157	(13.98)	90	(15.41)	49	(15.31)	41	(15.53)
$10,000–$29,999	216	(19.23)	116	(19.86)	65	(20.31)	51	(19.32)
$30,000–$49,999	133	(11.84)	70	(11.99)	39	(12.19)	31	(11.74)
$50,000–$69,999	105	(9.35)	49	(8.39)	19	(5.94)	30	(11.36)
≥ $70,000	235	(20.93)	106	(18.15)	60	(18.75)	46	(17.42)
Unknown	277	(24.67)	153	(26.2)	88	(27.50)	65	(24.62)
At least one household member smokes (parental report)	279	(24.84)	163	(27.91)	89	(27.81)	74	(28.03)

*p < 0.05 between Group 1 and Group 2

Table II

Comparison of central measures of obesity with BMI percentiles in all study participants.

Obesity measures	BMI percentile (%)						P value
	≤ 25%		> 25% – < 85%		≥ 85%		
Waist circumference (cm)	n	(%)	n	(%)	n	(%)	
≤ 25%	49	(43.75)	61	(54.46)	2	(1.79)	<0.0001
> 25% – < 85%	51	(17.0)	223	(74.33)	26	(8.67)	
≥ 85%	1	(1.43)	26	(37.14)	43	(61.43)	
Waist to height ratio							
≤ 25%	63	(52.94)	54	(45.38)	2	(1.68)	<0.0001
> 25% – < 85%	37	(12.37)	246	(82.27)	16	(5.35)	
≥ 85%	1	(1.56)	10	(15.63)	53	(82.81)	
Conicity index (m/√(kg/m))							
≤ 25%	28	(23.73)	83	(70.34)	7	(5.93)	<0.0001
>25% – < 85%	69	(23.23)	200	(67.34)	28	(9.43)	
≥ 85%	4	(5.97)	27	(40.30)	36	(53.73)	

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Table III

Unadjusted and adjusted OR (95% confidence interval) for the association between obesity measure with mild or moderate/severe asthma in children with allergic rhinitis

Obesity measures	No asthma		Mild asthma		Moderate/Severe asthma		Unadjusted OR (95% CI)	Adjusted OR* (95% CI)
BMI percentiles (%)	n	(%)	n	(%)	n	(%)		
≤ 25%	45	(38.79)	27	(23.28)	44	(37.93)	Reference	Reference
>25% – < 85%	110	(32.54)	99	(29.29)	129	(38.17)	1.15 (0.78–1.71)	0.92 (0.60–1.41)
≥ 85%	21	(24.42)	30	(34.88)	35	(40.69)	1.43 (0.86–2.39)	1.03 (0.59–1.79)
Waist circumference (cm)								
≤ 25%	27	(47.37)	13	(22.81)	17	(29.82)	Reference	Reference
>25% – < 85%	54	(31.58)	50	(29.24)	67	(39.18)	1.78 (1.01–3.15)†	1.40 (0.69–2.82)
≥ 85%	12	(27.27)	18	(40.91)	14	(31.82)	1.65 (0.80–3.39)	1.20 (0.49–2.92)
Waist to height ratio								
≤ 25%	21	(31.82)	23	(34.85)	22	(33.33)	Reference	Reference
>25% – < 85%	64	(39.51)	43	(26.54)	55	(33.95)	0.85 (0.51–1.44)	0.93 (0.54–1.60)
≥ 85%	5	(14.71)	13	(38.23)	16	(47.06)	1.91 (0.89–4.04)	2.00 (0.93–4.31)
Conicity index (m/√(kg/m))								
≤ 25%	23	(32.86)	27	(38.57)	20	(28.57)	Reference	Reference
>25% – < 85%	64	(40.0)	37	(23.12)	59	(36.88)	1.02 (0.61–1.69)	1.16 (0.67–2.01)
≥ 85%	3	(9.38)	15	(46.88)	14	(43.75)	2.15 (1.02–4.53) †	2.63 (1.19–5.82)†

Regression analysis was used to model the effect of each obesity measure on the likelihood of mild or moderate/severe asthma compared to allergic rhinitis without asthma.

* Adjusted for age group, race and gender.

† $p<0.05$

Table IV

Association of each obesity measure with FEV_1 in asthmatic children with or without allergic rhinitis

Obesity measures	Allergic rhinitis				No allergic rhinitis			
	n	Standardized β coefficient	Model R^2	P value	n	Standardized β coefficient	Model R^2	P value
BMI percentiles (kg/m^2)	139	0.24	0.08	0.005	46	0.53	0.31	0.0005
Waist circumference (cm)	56	0.19	0.15	0.17	27	0.51	0.19	0.04
Waist to height ratio	51	0.29	0.24	0.04	26	0.36	0.13	0.11
Conicity index ($m/\sqrt{(kg/m)}$)	51	0.23	0.20	0.12	26	−0.03	0.02	0.91

Adjusted for race, age group, gender, and income.

Table V

Unadjusted and age group, gender, and parental education-adjusted OR (95% CI) for the association of obesity measures with allergic sensitization in all study participants stratified by asthma diagnosis.

Obesity measure	Current asthma				No current asthma			
	n	(%)	Unadjusted OR (95% CI)	Adjusted* OR (95% CI)	n	(%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
BMI percentiles (%)								
≤25%	88	(21.84)	Reference	Reference	60	(22.06)	Reference	Reference
>25% – <85%	251	(62.28)	0.69 (0.44–1.08)	0.69 (0.44–1.09)	168	(61.76)	1.06 (0.63–1.79)	1.12 (0.65–1.92)
≥85%	64	(15.88)	0.50 (0.28–0.89)*	0.49 (0.27–0.90)*	44	(16.18)	0.66 (0.32–1.34)	0.77 (0.36–1.67)
Waist circumference (cm)								
≤25%	46	(23.71)	Reference	Reference	33	(20.89)	Reference	Reference
>25% – <85%	112	(57.73)	0.85 (0.49–1.48)	0.59 (0.29–1.19)	105	(66.46)	0.90 (0.48–1.71)	1.04 (0.48–2.24)
≥85%	36	(18.56)	0.63 (0.31–1.27)	0.38 (0.14–1.01)*	20	(12.66)	0.91 (0.35–2.34)	1.19 (0.36–3.94)
Waist to height ratio								
≤25%	47	(25.68)	Reference	Reference	34	(21.79)	Reference	Reference
>25% – <85%	106	(57.92)	0.89 (0.52–1.56)	1.13 (0.59–2.16)	105	(67.31)	2.54 (1.28–5.03)	2.48 (1.16–5.27)*
≥85%	30	(16.39)	0.60 (0.29–1.25)	0.72 (0.30–1.73)	17	(10.90)	2.87 (1.06–7.81)*	2.38 (0.76–7.46)
Conicity index (m/√(kg/m))								
≤25%	49	(26.78)	Reference	Reference	37	(23.72)	Reference	Reference
>25% – <85%	102	(55.74)	0.96 (0.55–1.68)	1.06 (0.56–2.00)	103	(66.03)	1.76 0.93–3.35)	1.95 (0.94–4.05)
≥85%	32	(17.49)	0.62 (0.30–1.25)	0.69 (0.29–1.66)	16	(10.26)	2.05 (0.78–5.37)	1.75 (0.57–5.38)

* $p \leq 0.05$

* Adjusted for age group, gender, and parental education

Table VI

OR and z-statistics for the association of the parameters examined with having asthma in the final (reduced) structural equation model

Parameter	Outcome=Asthma	
	OR	[estimated coefficient/standard error of the estimate]
Race		
Caucasian	0.94	−0.26
African American	1.56	**1.90**
Other	Reference	
Age (yrs)	0.89	**−2.95**
Pets in the home		
Cat	0.98	−0.12
Dog	0.89	−0.73
Cat and dog	0.80	−1.12
Other pets	Reference	
Gender		
Male	1.32	**2.23**
Female	Reference	
Obesity measures		
Waist circumference (cm)	2.95	**3.55**
Waist to height ratio	0.69	−1.13*
Conicity index (m/√(kg/m))	0.73	−1.39‡
Atopy index	0.98	−0.31

*Males (OR=2.43; [estimated coefficient/standard error of the estimate]=2.07)

‡Females (OR=0.43; [estimated coefficient/standard error of the estimate]= −2.88)