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Associations between Overweight and Obesity and Asthma Outcomes in Urban Adolescents

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Abstract

Objective—To examine the prevalence of overweight and obesity in urban adolescents with asthma and to investigate the relationships between anthropometric measures and asthma outcomes including quality of life, asthma control and lung function.

Methods—Adolescents with an asthma diagnosis, 12–20 years-old, were recruited from three urban communities in the United States. Spirometry and anthropometric data including height, weight, and waist circumferences were collected along with questionnaire data measuring quality of life, asthma control, and medication adherence. Body Mass Index (BMI) and waist-height ratio (WHtR) were computed.

Results—The sample (N=294) included 48% female and 80% African American. About 50% of the sample were either overweight or obese, and 41% had central obesity. No significant gender interactions with either BMI or WHtR on asthma outcomes were found. Neither BMI nor WHtR predicted quality of life, asthma control or medication adherence, while females had poorer quality of life and asthma control regardless of weight status ($p<.001$). Higher BMI or WHtR predicted higher spirometry values. Regardless of weight status, females had greater percent predicted spirometry values, while raw values (L) were significantly greater in males.

Conclusions—High BMI is a common comorbidity among poor, primarily African American, urban adolescents with asthma. The negative impact of being overweight or obese on quality of life or asthma control is yet to be manifested in adolescents. The findings underscore adolescence as an ideal period to safely intervene to reduce excessive body weight, which can prevent the potentially harmful effects of obesity on future asthma outcomes.

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Keywords

Body Mass Index (BMI); waist-height ratio (WHtR); quality of life; asthma control; medication adherence; lung function

Introduction

The obesity epidemic is a serious health threat to the public, particularly in children and adolescents in the United States (U.S.). Rapid growth and maturation, a variety of social factors and poor dietary habits, including excessive intake of fast food and sugar sweetened beverages, make adolescents particularly vulnerable to excess weight gain or high adiposity. According to recent national statistics in 2015–2016, the prevalence of obesity among adolescents between 12 and 19 years old was 20.6%, and the prevalence was higher among non-Hispanic blacks [1, 2]. Despite substantial clinical and policy efforts, the prevalence of obesity has not changed significantly in adolescents in the past 15 years [2]. Childhood obesity and its negative consequences carry into adulthood and often become intensified with age [3].

Asthma represents a common health concern in many adolescents, with 10% of U.S. adolescents 12 to 17 years of age reporting a current asthma diagnosis in 2015 [4]. Obesity is increasingly recognized as a common comorbidity of asthma, with the prevalence of obesity among youth with asthma nearing 50% [5–7]. Attaining optimal asthma control in adolescents has remained elusive, despite available highly effective treatment options, particularly in the presence of obesity. Studies have invariably reported a heightened burden of asthma in association with an increased body mass index (BMI) in children and adolescents [5, 7, 8]. Children with an increased BMI and asthma report a greater likelihood of poorly controlled asthma, severe symptom exacerbation, urgent healthcare utilization, and longer hospital stays for asthma and poorer quality of life compared to their lean counterparts [6, 9–12]. Obesity is also found to complicate asthma treatments. Reduced response to bronchodilators and long-term controller medications [9, 13, 14] and slow recovery from an acute exacerbation [11, 12] have been documented in association with obesity, resulting in further compromised lung function and frequent asthma related urgent healthcare utilization in children [14].

The literature provides some evidence suggesting gender differences in the associations between obesity and asthma control in children, although findings are mixed. Some reported poorly controlled asthma in urban adolescent females with higher BMI, but not in their male counterparts [15]. Others noted less controlled asthma among obese boys compared to those of normal weight while better asthma control was reported among obese African American girls [7]. Given the conflicting findings, there is a need to reassess the gender relationships between body weight and asthma control in urban adolescents.

This study is an extension of the literature exploring the associations between body weight and asthma outcomes in urban adolescents with particular attention to gender differences. The majority of prior studies have primarily relied on BMI for body weight classification. BMI is known to be an inadequate measure to determine adiposity status given its inability to distinguish lean mass from fat mass [16]. Consequently, individuals with large muscle mass could be inappropriately classified as being obese when using BMI alone. Conversely, individuals with minimal muscle mass and high fat mass could be inappropriately classified as having a healthy weight. Therefore, we included waist circumferences in addition to BMI as an index of adiposity. Waist circumference is a measure of central adiposity and denotes metabolically active fat tissue (visceral fat) more readily than BMI [17]. Waist circumference can distinguish children who may have a normal or healthy BMI but are centrally obese. The growing nature of children challenges the inadequacy of using waist circumference alone as an anthropometric indicator. Waist circumference adjusted to height (waist-height ratio [WHtR]) has been recommended to identify those with central obesity in children and adolescents [18–20].

The purpose of the study is twofold: (1) to examine the prevalence of overweight or obese categories in urban, predominately poor and minority, adolescents with asthma and its association with sociodemographic factors; (2) to investigate the relationships between anthropometric parameters (i.e., BMI and WHtR) and treatment adherence and asthma outcomes including asthma control, quality of life, and lung function. We hypothesized that adolescents with high BMI or WHtR would be less adherent to asthma treatment and report poorer asthma control, quality of life or lung function compared to their lean counterparts.

Methods

Settings and Sample

Adolescent participants, predominantly African American, were recruited from three U.S. metropolitan cities located in New York, Maryland, and Tennessee through clinician or school referrals, word-of-mouth, or direct recruitment at community venues or clinics. Eligibility criteria included (1) ages between 12 and 20 years old, (2) having physician-diagnosed asthma at least one year, (3) asthma-related health care utilization in the past 12 months preceding enrollment, (4) primary residence in the participating urban cities based on zip codes or school districts and (5) English proficiency. Those with chronic comorbid conditions producing asthma-like symptoms (e.g., cystic fibrosis, heart disease, etc.) or known metabolic disorders (e.g., diabetes), as reported by parents, were excluded.

Study Measurements

Body Mass Index (BMI)—Weight and height were measured by trained research assistants in each site. BMI was computed by dividing weight in kilograms by height in meters squared (kg/m^2), and the corresponding BMI-for-age percentile was determined based on gender specific BMI-for-age growth charts from the Center for Disease Control and Prevention (CDC) [21]. According to the CDC classification, underweight was defined as BMI $<5^{th}$ percentile, normal or health weight as BMI $\geq 5^{th}$ percentile but $< 85^{th}$ percentile, overweight as BMI $\geq 85^{th}$ but $<95^{th}$ percentile, and obese as BMI $\geq 95^{th}$ percentile.

Waist to Height Ratio (WHtR)—Waist circumference was measured in centimeters using a tape measure that was placed horizontally around the waist, just above hipbones, of the subjects in a standing position. Measurement was done just after expiration. We computed

WHtR by dividing waist circumference (cm) by height (cm), and used a threshold of 0.5 or above to identify those with central obesity or at high risk for metabolic syndrome [18–20].

Pediatric Asthma related Quality of Life—This measure is comprised of three subscales including activity (5 items), emotional function (8 items), and symptoms (10 items) [22]. This scale is extensively used, and its validity and reliability have been supported in studies of adolescents [22]. The total score was computed for each subscale, with higher scores indicating higher functioning in each subdomain. Cronbach's alphas of activity, emotion, and symptom subscales in the current sample were .84, .91 and .94, respectively.

Asthma Control Questionnaire (ACQ)— The measure assesses the range of clinical impairment a person experiences in relation to asthma. The original form contains seven items measured on a 7-point scale, from 0 (no impairment) to 6 (extreme impairment). We used the 6-item version void of an item concerning FEV1% predicted pre-bronchodilator. This 6-item version has been found comparable to the full version in its performance [23]. The questionnaire has been validated in children and adolescents 6 to 16 years of age [24]. The mean score of the six items was computed, with higher scores indicating greater impairment. Cronbach alpha of the measure in the current sample was .86.

Medication Adherence—Horne's 4-item Medication Adherence Report Scale (MARS) [25] was administered to assess self-reported adherence based on the extent of an individual's general tendency to forget to take or intentionally alter or miss medication. Each item was measured on a 5-point scale ranging from 1 (very often) to 5 (never), and sum scores ranging from 4 to 20 were computed, with higher scores indicating higher levels of adherence. Cronbach alpha in the current sample was .77.

Forced Expiratory Volume (FEV1) and Forced Vital Capacity (FVC) were obtained in accordance with the ATS/ERS standardization [26] using a portable KoKo® spirometer. We considered both percent predicted values (i.e., FEV1% and FVC%) and absolute (observed) values measured in liter (L) of these parameters. Absolute values were used to remedy duplicate adjustment of body weight and height on both outcome measures (% predicted pulmonary function) and the predictor, BMI categorization.

Sociodemographic (age, gender, SES) and asthma-related (medication, age at asthma diagnosis, and family history of asthma) information was completed by parents. Family asthma history was determined based on a report of asthma diagnosis in biological parent or sibling.

Research Participant Protection

The study protocol was reviewed and approved by the Institutional Review Boards in academic institutions affiliated with the study team at each site. Informed parent permission and adolescent assent were obtained prior to data collection. Older adolescents age 18 or older consented for themselves. Study questionnaires were completed at enrollment, and anthropometric and spirometry data were collected prior to participation in an intervention program.

Data Analysis

Frequency analysis was conducted to describe sample characteristics and calculate the prevalence of overweight or obese category and central obesity. Subsequently, Chi-Squares were computed to compare the prevalence between different subgroups by sociodemographic characteristics, family history of asthma, and the timing of asthma onset. BMI percentiles were dichotomized into a underweight or normal weight category (Under/ Normal) and an overweight or obese category (Over/Obese) because a high proportion (31.3%) of them were >95th percentile, violating the normality assumptions for statistical tests of continuous values. WHtR was not dichotomized for inferential statistics given the normal distribution of the data. Multiple linear regressions were fit to predict treatment adherence and asthma outcomes (i.e., quality of life, asthma control, FEV1, and FVC) associated with the Over/Obese category or WHtR adjusted for covariates including gender, age, household income, family history of asthma and site that had significant associations with one or more outcome measures. Estimates of the difference between Over/Obese and the reference category (Under/Normal) and the WHtR slope were calculated along with 95% confidence intervals (95% CI) and p-values for the strength of the effect. We also tested for gender interactions with the main effects. Residual analysis was examined for linear models to look for outliers, influential points, and overdispersion. The Box-Cox method was used to select a log-transformation of the ACQ scores because the residuals did not follow the regression assumptions on the linear scale. Otherwise, there were no substantial departures from the model assumptions.

Results

Sample Characteristics and Descriptions of Study Variables

A total of 373 adolescents from Buffalo NY (n=154), Baltimore MD (n=100), and Memphis TN (n=119) initially enrolled in the study. Of those, this study sample included only 294 adolescents whose anthropometric and spirometry data were available for analyses. Table 1 summarizes the demographic characteristics of the sample and descriptive statistics of study variables. The majority of participants were non-White, predominantly African American, and poor. The proportion of white participants at the NY site (30%) was significantly higher than that of the other two sites (2–3%) (Chi-Square=46.1, p<.001). In addition, the NY site had a significantly higher FVC (0.31 L more, p<0.0005) and FEV1 (0.31 L, p<0.0005) compared to the other two sites. Otherwise, there were no site differences in other sociodemographic characteristics, the rates of overweight/obesity by BMI or central obesity by WHtR, or outcome measures. Based on the ACQ's prespecified cut-offs (≥1.5 for uncontrolled), 42.2% (n=127) had uncontrolled asthma. Most of the sample (n=219, 74.5%) reported using at least one controller medication, and almost all participants (n=285, 97%) reported having a short-acting bronchodilator.

Prevalence of Overweight and Obese Categories and Central Obesity

Nearly 50% of the sample were either overweight (18.4%) or obese (31.3%) as determined by their BMI percentile, and 41% had central obesity based on WHtR (Table 1). Table 2 summarizes the prevalence of overweight/obese category by sociodemographic variables, family history of asthma, and age at diagnosis. Females were more likely to be overweight/

obese than males. Females or older teens had a greater likelihood of central obesity than males or younger counterparts.

Quality of Life and Asthma Control Predicted by BMI and WHtR

Initially, we tested for gender interactions with main effects of weight variables on quality of life and asthma control, and none of the interaction terms were significant (data are not provided). As such, subsequent regression models were conducted only with main effects without an interaction term. Table 3 summarized the results of regression models predicting quality of life and asthma control by BMI category or WHtR and gender after controlling for age, family history of asthma, household income and site. Teens with high BMI did not significantly differ from their lean counterparts in quality of life or asthma control. Similarly, there were no significant relationships between WHtR and these outcome measures of asthma. Female gender emerged consistently as a risk factor for poor quality of life ($p<0.001$) and asthma control ($p<0.001$) regardless of BMI or WHtR.

Adherence to Treatment Predicted by BMI and WHtR

We found no significant differences in medication adherence (MAS) or missed doses of daily controller medication between the overweight/obese group and their lean counterparts (B=−0.12 (−1.08, 0.83) p=.80, B=0.03 (−1.05, 1.10) p=.96, respectively) or based on WHtR (B=0.34 (−5.36, 4.69) p=.90, B=4.10 (−1.83, 10.03) p=.17, respectively) after controlling for the covariates.

Pulmonary Function Predicted by BMI category and WHtR

Pulmonary function was measured by percent predicted FEV1 and FVC as well as absolute values of these two parameters. Table 4 summarizes the results of regression models predicting spirometry parameters by BMI category or WHtR and gender after controlling for age, family history of asthma, household income and site. In general, higher BMI was significantly associated with greater FVC and FEV1 either %predicted or absolute value, while WHtR was positively associated only with FVC either %predicted or absolute value. Conflicting findings were noted between gender and the two types of pulmonary function values. Females had significantly greater %predicted FVC or FEV1, while FVC and FEV1 absolute values (L) were significantly higher in males.

Discussion

This study examined the prevalence of overweight and obesity in urban adolescents with asthma, and its relationships with multiple outcomes of asthma. In this study, nearly half of urban adolescents with asthma were classified into either overweight or obese category. The rate of obesity (31.3%) in this study is lower than that reported in two other inner-city studies of adolescents with asthma, 34% and 35.2% [15, 27], or a study of adolescents with asthma with racially diverse backgrounds, 46% [5]. Compared to the national prevalence of overweight (16.6%) or obese (16.1%) among urban adolescents in the U.S., predominantly African American, in 2017 [28], our rates and those in other studies of adolescents with asthma are substantially higher, suggesting widespread comorbidity between asthma and being overweight/obese in this population. The rate of central obesity, 41%, in this study is higher than 36.5% reported in U.S. adolescents aged 12–18 years or 29% among African American children and adolescents based on the same adiposity indicator, WHtR [29]. A study of Brazilian adolescents demonstrated 1.24 times higher odds of central obesity among those with asthma compared to those without [30]. Mechanical, metabolic and immunological changes associated with increasing body fat have been suggested as an underlying mechanism explaining the common occurrence of asthma and obesity [8, 9, 13]. Future study is needed to ascertain the mechanisms relating obesity and asthma in adolescents with asthma.

Similar to an earlier study of inner-city adolescents with asthma [15], we found that females were slightly more likely to be either overweight or obese or have central obesity than males. Unlike other studies suggesting higher overweight or obesity prevalence among younger children [5], our data did not show age differences in the prevalence. On the other hand, we noted that older teens had more central obesity than their younger counterparts, similar to the trend found in the national data of U.S. adolescents [29].

Overall, this study did not provide support for our hypothesis that high BMI or WHtR would be associated with poor asthma outcomes. First, we found no relationship between the anthropometric measures and overall quality of life, corroborating earlier studies in which obesity was not a risk factor for poor quality of life in children with asthma [10, 31], but contradicting another study reporting significant reduction in quality of life associated with obesity in pediatric patients [32]. In some studies, overweight or obese children with asthma have been found to be at greater risk for diminished physical activity levels [33, 34], due to reduced tolerance to exercise resulting from restrictions imposed by excessive fat on the chest wall. Our failure to observe activity limitation among overweight or obese adolescents may be due in part to the measure's reliance on the *perception* (e.g., feeling "bothered") of activity limitation. Because of adolescents' tendency to normalize or tolerate adverse conditions associated with asthma or obesity [35], they may not perceive certain activity limitations as *bothersome*. Therefore, to adequately gauge activity limitations in adolescents with asthma, it may be necessary to use an objective measure of physical activity such as an actigraphy device.

Consistent with many earlier reports based on children and adolescents [6, 31, 36–38], we found no increased risk of poor asthma control among teens with high BMI or WHtR compared to their lean counterparts. Furthermore, obesity did not seem to hinder urban children and adolescents from achieving or maintaining asthma control when treated [37]. In contrast, some studies of children or adolescents report high BMI or WHtR as a risk factor for poorly controlled asthma [5, 7, 10, 11, 39, 40]. Unlike our study in which females consistently reported poorer asthma control than males regardless of BMI or WHtR, the literature suggests different gender effects on the relationships between anthropometric measures and asthma control. Some studies demonstrated that the positive associations between BMI/body fat and symptom morbidity were found only in girls, but not in boys [15, 39], while others [7] observed a greater likelihood of poorly controlled asthma among obese boys and better controlled asthma in girls who were obese. A recent study conducted in Israel reported that the positive associations between being overweight and moderate-to-severe asthma were noted only in girls, while being underweight was associated with mild asthma only in boys [41]. Such gender differences led the authors to suspect different etiology in males than females explaining the associations between body weight and asthma morbidity. Further research is warranted to explore factors explaining the complex relationships between body weight/adiposity and asthma control by gender.

We found positive associations between BMI and pulmonary function (FEV1 and FVC) measured in either percent predicted or absolute values (L), while WHtR associated positively only with FVC. Such positive associations are in conflict with some reports in which excessive weight associated with poorer pulmonary function among overweight and obese adult patients with asthma [42]. However, available studies of pediatric patients paint a somewhat different picture that is more in line with our findings. While many studies [6, 14, 31, 33, 37, 43] of children found no relationships between BMI/body fat and pulmonary function, others [36, 38, 44] reported increased pulmonary function either percent predicted or absolute values (L) of FEV1 and FVC in overweight or obese children or adolescents with asthma, similar to our findings. A study [31] including both children and adults with asthma demonstrated significantly lower FVC in association with obesity in adults, but not in children, suggesting no apparent negative effects of obesity on lung function in young patients, *just yet*. Indeed, a recent meta-analysis [45] confirmed inverse relationships between BMI and pulmonary function in adults with asthma, while positive relationships in pediatric patients similar to our findings. As an explanation for the increased pulmonary function, specifically FVC, in relation to obesity in children with asthma, Forno [46] suggested an increased risk of an asymmetrical growth of the lungs and airways (airway dysanapsis) associated with overweight/obesity. Although further research is warranted to explore underlying reasons for the differences between children and adults, it is worth noting that no signs of compromised lung function is not an indication that obesity is harmless to lung health in adolescents with asthma. Given the inverse relationships between BMI and pulmonary function in adults [45], a cohort study is necessary to assess the long-term trajectory of pulmonary function from adolescence to adulthood responding to increasing body weight or adiposity.

Interestingly, when percent predicted spirometry parameters are considered, females had better pulmonary function, whereas spirometry absolute values (L) were higher in males regardless of weight status. Males' higher absolute values (L) simply indicate the fact that boys have greater lung function than girls in adolescence [44, 47]. On the other hand, females' higher percent predicted values may suggest that the extent to which asthma compromises lung function in females is smaller compared to males, given the percent predicted values being determined in comparison to a healthy reference population with similar characteristics (e.g., age, race, height, weight and gender). The conflicting relationships between gender and two different approaches to spirometry values underscores gender as an important moderator in investigating the adverse impact of asthma on lung function.

Study Limitations

This study has several limitations warranting caution in interpreting findings. First, the cross-sectional nature of the study prevents us from making inference to causality beyond associations between BMI status and lung function parameters. Second, this study does not include a body composition measure such as the analysis of dual-energy X-ray absorptiometry or bioelectrical impedance analysis that could have more directly and accurately assessed total body fat separate from other fat-free mass such as lean soft tissue and bones. Third, use of a convenience sample limits the generalizability of the findings to adolescents in other urban areas. Specifically, caution is required in generalizing our findings based on predominantly African American adolescents to those with other racial and ethnic background. In addition, the relatively small sample size in the study may have also contributed to non-significant associations between anthropometric measures and asthma outcomes. A lack of a control group without asthma also prevented us from comparing our prevalence with that of adolescents without asthma and determining whether the observed associations between BMI/WHtR and spirometry values would hold true for cases without asthma. Fourth, as a community based study, it was not feasible to conduct post-bronchodilator test to assess the degree of reversibility of airway limitation. Thus, we were unable to determine the impact of obesity on airway hyper-reactivity. Finally, due to the original study design, there was a time lag of 70 days on average between questionnaire data collected at enrollment and anthropometric data measured on the day of a camp intervention. Although the likelihood of any drastic changes in anthropometric measures during the time lag would be low, we reassessed the associations between questionnaire data and BMI/WHtR after adjusting for the time lag along with other covariates, which led to no changes in our findings (data are not shown).

Conclusions

Overall, this study demonstrates a high rate of co-occurrence between asthma and obesity in urban adolescents, particularly among females. It is not apparent that adolescents with high BMI or central obesity have more compromised quality of life, asthma control, or medication adherence compared to their lean counterparts. Ironically, adolescents with increased body weight appear to have better pulmonary function than their lean counterparts. This raises a question regarding the clinical meaningfulness of spirometry to assess the respiratory burden of obesity in adolescents with asthma. Taken all together, adolescents with high BMI or central obesity do not seem particularly vulnerable to untoward asthma outcomes. Perhaps, the physical and physiological resilience or plasticity characterizing adolescence may have protected these young people from harmful influences of obesity. Absence of statistical associations between high BMI or central obesity and adverse asthma outcomes does not discount the potentially detrimental long term impact of obesity on respiratory health in young people. Rather, the adolescent period ought to be considered a safe and opportune time for prevention and management of obesity through targeted interventions before it starts to take a toll on the health of young people with asthma.

Declaration of Interest and Acknowledge Statement

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References

1. Hales CM, Fryar CD, Carroll MD, Freedman DS, Ogden CL. Trends in obesity and severe obesity prevalence in us youth and adults by sex and age, 2007–2008 to 2015–2016. JAMA. 2018;319:1723–1725. [PubMed: 29570750]
2. Skinner AC, Ravanbakht SN, Skelton JA, Perrin EM, Armstrong SC. Prevalence of obesity and severe obesity in US children, 1999–2016. Pediatrics. 2018;141:e20173459. [PubMed: 29483202]
3. Center for Disease Control and Prevention. Childhood obesity facts. Available at: https://www.cdc.gov/healthyschools/obesity/facts.htm. Accessed October 1, 2018.
4. Center for Disease Control and Prevention. Most recent asthma data. Available at: https://www.cdc.gov/asthma/most_recent_data.htm. Accessed June/20, 2017.
5. Quinto KB, Zuraw BL, Poon KT, et al. The association of obesity and asthma severity and control in children. J Allergy Clin Immunol. 2011;128:964–969. [PubMed: 21820711]
6. Sah PK, Gerald Teague W, Demuth KA, Whitlock DR, Brown SD, Fitzpatrick AM. Poor asthma control in obese children may be overestimated because of enhanced perception of dyspnea. J Allergy Clin Immunol Pract. 2013;1:39–45. [PubMed: 23646295]
7. Borrell LN, Nguyen EA, Roth LA, et al. Childhood obesity and asthma control in the GALA II and SAGE II studies. Am J Respir Crit Care Med. 2013;187:697–702. [PubMed: 23392439]
8. Sivapalan P, Diamant Z, Ulrik CS. Obesity and asthma: Current knowledge and future needs. Curr Opin Pulm Med. 2015;21:80–85. [PubMed: 25405670]
9. Jensen ME, Wood LG, Gibson PG. Obesity and childhood asthma - mechanisms and manifestations. Curr Opin Allergy Clin Immunol. 2012;12:186–192. [PubMed: 22391755]
10. Manion AB, Velsor-Friedrich B. Quality of life and health outcomes in overweight and non-overweight children with asthma. J Pediatr Health Care. 2017;31:37–45. [PubMed: 26874457]
11. Carroll CL, Bhandari A, Zucker AR, Schramm CM. Childhood obesity increases duration of therapy during severe asthma exacerbations. Pediatr Crit Care Med. 2006;7:527–531. [PubMed: 17006390]
12. Shanley LA, Lin H, Flores G. Factors associated with length of stay for pediatric asthma hospitalizations. J Asthma. 2015;52:471–477. [PubMed: 25375904]
13. Sutherland ER. Linking obesity and asthma. Ann N Y Acad Sci. 2014;1311:31–41. [PubMed: 24517401]
14. Forno E, Lescher R, Strunk R, et al. Decreased response to inhaled steroids in overweight and obese asthmatic children. J Allergy Clin Immunol. 2011;127:741–749. [PubMed: 21377042]
15. Kattan M, Kumar R, Bloomberg GR, et al. Asthma control, adiposity, and adipokines among inner-city adolescents. J Allergy Clin Immunol. 2010;125:584–592. [PubMed: 20226295]
16. Forno E Childhood obesity and asthma: To BMI or not to BMI? J Allergy Clin Immunol. 2017;139:767–768. [PubMed: 27658759]
17. Papoutsakis C, Chondronikola M, Antonogeorgos G, et al. Associations between central obesity and asthma in children and adolescents: A case–control study. J Asthma. 2015;52:128–134. Available from: 10.3109/02770903.2014.954291. [PubMed: 25134781]
18. McCarthy HD, Ashwell M. A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message--'keep your waist circumference to less than half your height'. Int J Obes (Lond). 2006;30:988–992. [PubMed: 16432546]
19. Ochoa Sangrador C, Ochoa-Brezmes J. Waist-to-height ratio as a risk marker for metabolic syndrome in childhood. A meta-analysis. Pediatr Obes. 2018;13:421–432. [PubMed: 29700992]
20. Bacopoulou F, Efthymiou V, Landis G, Rentoumis A, Chrousos GP. Waist circumference, waist-to-hip ratio and waist-to-height ratio reference percentiles for abdominal obesity among greek adolescents. BMC Pediatr. 2015;15:50–015-0366-z. [PubMed: 25935716]
21. Center for Disease Control and Prevention. About child and teen BMI. Available at: https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html. Accessed 11/30, 2017.

22. Juniper EF, Guyatt GH, Feeny DH, Ferrie PJ, Griffith LE, Townsend M. Measuring quality of life in children with asthma. Qual Life Res. 1996;5:35–46. Available from: http://www.jstor.org/stable/4034778. [PubMed: 8901365]

23. Juniper EF, Svensson K, Mork AC, Stahl E. Measurement properties and interpretation of three shortened versions of the asthma control questionnaire. Respir Med. 2005;99:553–558. [PubMed: 15823451]

24. Juniper EF, Gruffydd-Jones K, Ward S, Svensson K. Asthma control questionnaire in children: Validation, measurement properties, interpretation. Eur Respir J. 2010;36:1410–1416. [PubMed: 20530041]

25. Horne R, Weinman J. Patients' beliefs about prescribed medicines and their role in adherence to treatment in chronic physical illness. J Psychosom Res. 1999;47:555–567. [PubMed: 10661603]

26. Miller MR, Hankinson J, Brusasco V, et al. Standardisation of spirometry. Eur Respir J. 2005;26:319–338. [PubMed: 16055882]

27. Groth SW, Rhee H, Kitzman H. Relationships among obesity, physical activity and sedentary behavior in young adolescents with and without lifetime asthma. J Asthma. 2016;53:19–24. [PubMed: 26288155]

28. Kann L, McManus T, Harris WA, et al. Youth risk behavior surveillance - united states, 2017. Morbidity and mortality weekly report. Surveillance summaries (Washington, D.C.: 2002). 2018;67:1–114. Available from: https://www.ncbi.nlm.nih.gov/pubmed/29902162;https://www.ncbi.nlm.nih.gov/pmc/PMC6002027/.

29. Xi B, Mi J, Zhao M, et al. Trends in abdominal obesity among U.S. children and adolescents. Pediatrics. 2014;134:e334–9. [PubMed: 25049347]

30. Jobim Benedetti F, Lucia Bosa V, Mariante Giesta J, Bueno Fischer G. Anthropometric indicators of general and central obesity in the prediction of asthma in adolescents; central obesity in asthma. Nutr Hosp. 2015;32:2540–2548. [PubMed: 26667701]

31. Peters JI, McKinney JM, Smith B, Wood P, Forkner E, Galbreath AD. Impact of obesity in asthma: Evidence from a large prospective disease management study. Ann Allergy Asthma Immunol. 2011;106:30–35. [PubMed: 21195942]

32. Scott S, Currie J, Albert P, Calverley P, Wilding JPH. Risk of misdiagnosis, health-related quality of life, and BMI in patients who are overweight with doctor-diagnosed asthma. Chest. 2012;141:616–624. [PubMed: 21868466]

33. Pianosi PT, Davis HS. Determinants of physical fitness in children with asthma. Pediatrics. 2004;113:e225–e229. [PubMed: 14993581]

34. Holderness H, Chin N, Ossip DJ, Fagnano M, Reznik M, Halterman JS. Physical activity, restrictions in activity, and body mass index among urban children with persistent asthma. Ann Allergy Asthma Immunol. 2017;118:433–438. [PubMed: 28268134]

35. Mammen JR, Rhee H, Norton SA, Butz AM. Perceptions and experiences underlying self-management and reporting of symptoms in teens with asthma. J Asthma. 2017;54:143–152. [PubMed: 27337035]

36. Tantisira KG, Litonjua AA, Weiss ST, Fuhlbrigge AL. Association of body mass with pulmonary function in the childhood asthma management program (CAMP). Thorax. 2003;58:1036–1041. [PubMed: 14645968]

37. 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;43:661–666. Available from: 10.1080/02770900600925270. [PubMed: 17092846]

38. Lang JE, Holbrook JT, Wise RA, et al. Obesity in children with poorly controlled asthma: Sex differences. Pediatr Pulmonol. 2013;48:847–856. Available from: https://doi-org.ezpminer.urmc.rochester.edu/10.1002/ppul.22707. [PubMed: 23143849]

39. Ekstrom S, Magnusson J, Kull I, et al. Body mass index development and asthma throughout childhood. Am J Epidemiol. 2017;186:255–263. [PubMed: 28838063]

40. Forno E, Acosta-Pérez E, Brehm JM, et al. Obesity and adiposity indicators, asthma, and atopy in Puerto Rican children. J Allergy Clin Immunol. 2014;133:1308–1314.e5. [PubMed: 24290290]

41. Machluf Y, Farkash R, Fink D, Chaiter Y. Asthma severity and heterogeneity: Insights from prevalence trends and associated demographic variables and anthropometric indices among Israeli adolescents. J Asthma. 2018;55:826–836. Available from: 10.1080/02770903.2017.1373809. [PubMed: 28872935]
42. Strunk RC, Colvin R, Bacharier LB, et al. Airway obstruction worsens in young adults with asthma who become obese. J Allergy Clin Immunol Pract. 2015;3:765–71.e2. [PubMed: 26164807]
43. Jensen ME, Gibson PG, Collins CE, Wood LG. Lean mass, not fat mass, is associated with lung function in male and female children with asthma. Pediatr Res. 2014;75:93–98. [PubMed: 24129552]
44. Chen YC, Huang YL, Ho WC, Wang YC, Yu YH. Gender differences in effects of obesity and asthma on adolescent lung function: Results from a population-based study. J Asthma. 2017;54:279–285. [PubMed: 27435689]
45. Forno E, Han YY, Mullen J, Celedon JC. Overweight, obesity, and lung function in children and adults-A meta-analysis. J Allergy Clin Immunol Pract. 2017;6:570–581. [PubMed: 28967546]
46. Forno E, Weiner DJ, Mullen J, et al. Obesity and airway dysanapsis in children with and without asthma. Am J Respir Crit Care Med. 2017;195:314–323. [PubMed: 27552676]
47. Becklake MR, Kauffmann F. Gender differences in airway behaviour over the human life span. Thorax. 1999;54:1119–1138. [PubMed: 10567633]

Table 1.

Sample characteristics (N=294)

Sex	
Male, n (%)	153 (52)
Female, n (%)	141 (48)
Age, mean (std)	14.58 (1.92)
12–14, n (%)	141 (48)
15–20, n (%)	153 (52)
Race	
White, n (%)	39 (13.3)
Nonwhite	
Black or African American, n (%)	235 (79.9)
Other, n (%)	4 (1.4)
Multi race, n (%)	16 (5.4)
Ethnicity	
Hispanic/ Latino, n (%)	22 (7.5)
Annual household income	
≤ $30,000, n (%)	166 (56.5)
>$30,000, n (%)	123 (41.8)
Missing n (%)	5 (1.7)
Family history of asthma	
No, n (%)	114 (38.8)
Yes, n (%)	180 (61.2)
Age at asthma diagnosis, mean (std)	4.18 (4.28)
< 6 years old, n (%)	198 (68.4)
≥ 6 years old, n (%)	96 (32.6)
Weight classification by BMI percentile	
Underweight, n(%)	6 (2.0)
Normal Weight, n(%)	142 (48.3)
Overweight, n(%)	54 (18.4)
Obese, n(%)	92 (31.3)
Waist-Height Ratio (WHtR), mean (std), range	0.5 (0.1), 0.35–0.86
≥ 0.5, n(%)	115 (41%)
< 0.5, n(%)	163 (59%)

Table 2.

Comparisons between subgroups of adolescents in the proportions of underweight/normal weight (Under/Normal) and overweight/obese (Over/Obese), and waist-height ratio (WHtR).

		BMI Categories (n=294)					WHtR (n=278)		
		Under/ Normal n (%)	**Over/ Obese n (%)**	**X^2**	**p**	**<0.5 n (%)**	**≥0.5 n (%)**	**X^2**	**p**
Gender	Male	86 (56.2)	67 (43.8)	3.92	<.05	96 (66.2)	49 (33.8)	6.53	.01
	Female	62 (44.0)	79 (56.0)			67 (50.4)	66 (49.6)		
Age (years)	12–14	73 (51.8)	68 (48.2)	0.13	.72	89 (66.9)	44 (33.1)	6.58	.01
	15–20	75 (46.4)	78 (53.6)			74 (51.0)	71 (49.0)		
Race	White	21 (53.8)	18 (46.2)	0.09	.77	25 (64.1)	14 (35.9)	0.33	.57
	Non-white	127 (49.8)	128 (50.2)			138 (57.7)	101 (42.3)		
Household income	≤$30k	83 (50.0)	83 (50.0)	0.00	1.00	43 (57.3)	32 (42.7)	0.03	.88
	>$30k	62 (50.4)	61 (49.6)			118 (59.3)	81 (40.7)		
Family asthma	Yes	90 (50.0)	90 (50.0)	0.00	.98	101 (60.5)	66 (39.5)	0.41	.52
	No	58 (50.9)	56 (49.1)			62 (55.9)	49 (44.1)		
Age at diagnosis	< 6	104 (52.5)	94 (47.5)	0.91	.34	112 (59.9)	75 (40.1)	0.23	.63
	≥ 6	44 (45.8)	52 (54.2)			51 (56.0)	40 (44.0)		

Under/Normal: underweight or normal weight; Over/Obese: overweight or obese

Table 3.

Quality of life and asthma control predicted by gender, BMI category and waist to height ratio (WHtR) after adjusting for covariates including age, history of family asthma, family income, and site.

	BMI as predictor (n=289)		WHtR as predictor (n=274)	
	Gender (male=1, female=2), B (95%CI)	BMI category (under/ normal=1, over/obesity=2) B (95%CI)	Gender (male=1, female=2) B (95%CI)	WHtR B (95%CI)
Quality of Life-total	−16.84 (−23.96, −9.72) p<.001	−5.62 (−12.59, 1.34) p=.11	−18.06 (−25.39, −10.73) p<.001	−13.00 (−49.91, 23.92) p=.49
Activity subscale	−3.25 (−4.81, −1.68) p<.001	−1.29 (−2.82, 0.25) p=.10	−3.41 (−5.01, −1.81) p<.001	−5.63 (13.70, 2.44) p=.17
Emotional function subscale	−5.80 (−8.43, −3.17) p<.001	−2.22 (−4.79, 0.36) p=.09	−6.18 (−8.89, −3.47) p<.001	−3.57 (17.20, 10.06) p=.61
Symptom subscale	−7.79 (−11.12, −4.47) p<.001	−2.12 (−5.37, 1.13) p=.20	−8.47 (−11.90, −5.04) p<.01	−3.80 (21.07, 13.47) p=.67
Asthma control	0.14 (0.07, 0.22) p<.01	0.04 (−0.03, 0.11) p=.25	0.15 (0.08, 0.23) P<.01	0.26 (0.12, 0.63) p=.18

Table 4.

FEV1 and FVC predicted by gender and BMI category and waist to height ratio (WHtR) after adjusting for covariates including age, history of family asthma, family income, and site.

	BMI as a predictor (n=289)		WHtR as a predictor (n=274)	
	Gender (male=1, female=2) B (95%CI)	BMI category (under/ normal=1, over/obesity=2) B (95%CI)	Gender (male=1, female=2) B (95%CI)	WHtR B (95%CI)
FVC, %predicted	4.22 (0.73, 7.71) p=.02	6.44 (3.02, 9.85) p<.01	4.10 (0.43, 7.77) p=.03	20.69 (2.20, 39.17) p=.03
FEV1, %predicted	4.09 (−0.03, 8.20) p=.05	4.52 (0.49, 8.55) p=.03	4.29 (0.03, 8.54) p=.05	4.11 (−17.31, 25.53) p=.71
FVC (L), absolute value	−0.60 (−0.77, −0.43) p<.01	0.39 (0.23, 0.56) p<.01	−0.63 (−0.80, −0.45) P<0.01	0.98 (0.08, 1.88) p=.03
FEV1 (L), absolute value	−0.41 (−0.57, −0.25) p<.01	0.26 (0.11, 0.42) p<.01	−0.42 (−0.58, −0.25) P<0.01	0.31 (−0.52, 1.41) p=.46