Published in final edited form as:

Pediatr Pulmonol. 2012 November ; 47(11): 1061–1069. doi:10.1002/ppul.22547.

Associations of Obesity and Asthma with Functional Exercise Capacity in Urban Minority Adolescents

Deepa Rastogi, MBBS, MS¹, Unab I. Khan, MD, MS², Carmen R. Isasi, MD, PhD³, and Susan M. Coupey, MD²

¹Division of Respiratory & Sleep Medicine, Department of Pediatrics, Children's Hospital at Montefiore/Albert Einstein College of Medicine

²Division of Adolescent Medicine, Department of Pediatrics, Children's Hospital at Montefiore/Albert Einstein College of Medicine

³Department of Epidemiology and Population Health, Albert Einstein College of Medicine

Summary

Purpose—To examine the independent association of asthma and obesity and of their coexistence with functional exercise capacity among urban adolescents.

Methods—One hundred and eighteen Hispanic and African American adolescents including 33 obese asthmatics, 18 normal-weight asthmatics, 38 obese non-asthmatics and 29 normal-weight non-asthmatics underwent anthropometric measures, 6 minute walk test (6MWT) as measure of functional exercise capacity and spirometry as measure of pulmonary function. The 6 minute walk distance (6MWD) was compared between the four study groups. The association of 6MWD with measures of lower airway obstruction, and measures of adiposity was assessed.

Results—The 6MWD was lower among the obese groups with the least distance covered by the obese asthmatic group ($p=0.02$). In the obese asthmatic group, there was a negative correlation between 6MWD and body mass index (BMI) ($r=-0.35$, $p=0.03$) but no association was noted with percent-predicted Forced Expiratory Volume in the 1st second (FEV₁) ($r=0.07$, $p=0.70$). Conversely, the 6MWD correlated with FEV₁ among normal-weight asthmatics ($r=0.45$, $p=0.04$) and normal-weight non-asthmatics ($r=0.4$, $p=0.03$) but was not associated with BMI in either of the two groups. After adjusting for age, height, gender and ethnicity, BMI was noted to be a significant predictor (-2.76 , 95% CI -4.77 – -0.76 , $p<0.01$) of the 6MWD among the obese while percent predicted FEV₁ (1.87 , 95% CI 0.28 – 3.45 , $p=0.02$) was a significant predictor among the normal-weight participants.

Conclusions—Our findings suggest that among urban minority obese asthmatic adolescents, functional exercise capacity was associated with obesity, rather than pulmonary function.

Keywords

Asthma; Obesity; Functional Exercise Capacity; Adolescents

Corresponding author: Deepa Rastogi, MBBS, MS, Joseph S. Blume Faculty Scholar in Pediatric Development, Assistant Professor of Pediatrics, Albert Einstein College of Medicine, 3415 Bainbridge Ave, Bronx, NY 10467, drastogi@montefiore.org, Phone: (718)-515-2330, Fax: (718)-515-2608.

The authors do not have any conflict of interest with the materials included in this manuscript

Introduction

Prevalence of both childhood obesity^{1,2} and asthma³ have been increasing over the past four decades, particularly among urban minority children and youth. Several studies have reported an association between asthma and obesity^{4–9} with asthmatic children having a higher BMI than their non-asthmatic counterparts.^{10,11}

Decreased physical activity is one of the mechanisms proposed for the co-existence of asthma and obesity¹². Children with asthma are less physically active than non-asthmatic children^{11,13,14}, likely due to poor asthma control.^{11,13} As obese children with asthma have lower FEV₁/FVC ratio than lean asthmatics^{15–17}, it may be hypothesized that lower airway obstruction contributes to decreased physical activity among obese asthmatics. However, objective evaluation of exercise capacity utilizing maximal exercise testing did not find an association between exercise capacity and asthma severity, primarily among young children.¹⁸ While functional exercise capacity measured by 6 minute walk test (6MWT)¹⁹ is reflective of daily physical activity among those with lower airway obstruction, there is a lack of reports on its application among adolescents with obesity and asthma. Although some studies have investigated the association of functional exercise capacity with BMI²⁰, the specific individual effects of obesity and asthma and that of their co-existence on functional exercise capacity have not been extensively evaluated.

To address these aspects, we investigated the relationship of functional exercise capacity, measured by the distance covered in 6MWT, with pulmonary function and anthropometric indices among urban minority adolescents. We hypothesized that adolescents with both obesity and asthma will have a lower functional exercise capacity as measured by shorter 6 minute walk distance (6MWD) than adolescents with either asthma or obesity or neither. We also hypothesized that functional exercise capacity will correlate with anthropometric measures rather than pulmonary function among obese asthmatics.

Materials and Methods

Study population

Hispanic and African American adolescents, ages 12–21 years, were recruited during their routine health care visits to the outpatient clinics at the Children's Hospital at Montefiore, Bronx, NY between 6/2007 and 6/2009. We chose to include these two ethnic groups because they are the groups most affected by obesity and asthma. Participants were selected into the study based on the presence of obesity with or without asthma. Normal weight adolescents with or without asthma were also included as comparison groups. Therefore, the study was designed to include participants in 4 study groups, of 35 subjects per group: 1. Obese asthmatics 2. Normal weight asthmatics 3. Obese non-asthmatics 4. Normal weight non-asthmatics.

Obesity was defined as BMI >95th percentile and normal weight was defined as BMI <85th percentile for age and sex. Adolescents with asthma were those diagnosed by their primary care provider on the basis of wheeze and documented bronchodilator responsiveness in accordance with National Heart Lung and Blood Institute Expert Panel Report-3 (NHLBI EPR-3).²¹ As confirmed on their electronic medical records, adolescents with asthma had a history of emergency room (ER) visits and/or hospitalizations for asthma exacerbations. Additionally, 85.7% of asthmatic adolescents recruited for the study were under the care of a pediatric pulmonologist with monitoring including spirometry testing at each follow up visit. Because another aspect of the study was to examine systemic inflammation as the primary outcome of the study, participants with a history of other co-existing medical conditions and asthmatics with systemic steroid use in the preceding 3 months were excluded.

Recruitment Procedures—Health care providers were informed about the study and asked to inform research assistants of potentially eligible participants, after verifying eligibility with review of EMR and calculated BMI. After completion of their health care visit, research assistants approached these potential participants and their parents to describe the goals of the study and invite them to participate. Informed consent was obtained from both participants and their parents who agreed to participate. The study visit was scheduled within 2 days of obtaining consent. Participants were asked to go to the Clinical Research Center (CRC) located at the Montefiore Medical Center for their study appointment. The study was conducted with the approval of the Montefiore Medical Center Institutional Review Board. All study records were stored in compliance with Health Insurance Portability and Accountability Act (HIPAA) regulations.

Of the 200 participants who signed the consent form, 118 returned for the study visit to complete the spirometry and 6MWT. The study sample was comprised of 33 obese asthmatics, 18 non-obese asthmatics, 38 obese non-asthmatics and 29 non-obese non-asthmatic controls. Of the 118 participants, 66% were insured by Medicaid.

Study measures

Anthropometrics—Height and weight were obtained on a Scaletronix® stadiometer on all study participants. BMI and BMI z-score were calculated using Epi Info.²²

Asthma severity—All asthmatics were clinically stable at the time of recruitment. Details of daytime and night time symptom frequency and the preventative medication regimen were obtained to classify asthma severity as per the NHLBI EPR-3 guidelines.²¹

Pulmonary function testing—Pulmonary function testing was performed on VMax 229 spirometer (Sensormedics Corp., Yorba Linda, CA). Adolescents with asthma were instructed to not use albuterol on the day of testing. All tests were performed by a single trained respiratory therapist according to the American Thoracic Society (ATS) guidelines.²³ Of the 3 complete maneuvers, the most optimal effort was retained for analysis. National Health and Nutritional Examination Survey (NHANES) reference values were used to obtain the percent predicted values of spirometry indices²⁴ included in the analysis, namely Forced Vital Capacity (FVC), FEV₁, their ratio FEV₁/FVC and mid expiratory flow rates (FEF_{25–75%}). FEV₁, FEV₁/FVC ratio and FEF_{25–75%} were used as measures of lower airway obstruction.

6-Minute Walk Test—In accordance with the ATS guidelines²⁵, all participants underwent the 6-minute walk test (6MWT) as a measure of functional exercise capacity. The adolescents were asked to wear comfortable clothing and athletic shoes. Those with asthma were instructed not to use albuterol on the day of the testing. A trained research nurse conducted the test during the study visit in an empty corridor marked to define a course of 30 meters. The nurse remained at one end of the marked course during testing and instructed the participants in keeping with the ATS guidelines. The 6-minute walk distance (6MWD), measured in meters, was the primary outcome measure of interest. Heart rate and Borg Dyspnea Index²⁶ were obtained at rest and after completion of the test.

Statistical Analysis

Descriptive analysis was performed on demographic, anthropometric, spirometric and 6MWT measures; the results are depicted as mean ± standard deviation (SD). With sample sizes of 18 to 38 in the study groups, this study had a power of 84% to detect the observed differences with α set at 0.05. These observed differences were similar to clinically

meaningful differences reported in the literature.^{27, 28} In addition, we had 83% power to detect a correlation coefficient of 0.4 with α set at 0.05.

Parametric tests were applied since all variables were normally distributed, as evaluated with Shapiro-Francia Normality test. Continuous variables, including 6MWD, were compared between the four study groups using Analysis of Variance (ANOVA). Bonferroni post hoc analysis was done only when ANOVA was statistically significant. Association of the 6MWD with ethnicity and gender was obtained by T-test and its correlation with age, pulmonary function parameters and BMI was obtained by Pearson correlation. Asthma severity was compared between the asthma groups by Chi-square testing. Linear regression analysis was performed to examine the association of the 6MWD with BMI and FEV₁ when adjusted for age, gender and ethnicity. In addition to BMI and FEV₁, ethnicity was included in the model because of its significant association with 6MWD in univariate analysis. Gender, height, and age were included they are potential confounders of the 6MWD²⁵ and because of the differences in their distribution between the study groups. The model was stratified by obesity to identify any confounding by BMI but could not be stratified by asthma status due to fewer participants in the normal-weight asthma category. All tests of association were two tailed and conducted with the type I error rate set *a priori* at 0.05. Statistical analyses were performed using the STATA statistical software version 10 (College Station, TX).

Results

Demographics, anthropometrics, spirometry and asthma severity

Comparison of the demographic, anthropometric and spirometry variables is summarized in Table 1. BMI was borderline higher among African Americans ($33.96 \pm 9.09 \text{ kg/m}^2$) than Hispanics ($30.77 \pm 9.55 \text{ kg/m}^2$) ($p=0.06$) for the entire study sample. Obese asthmatic and obese non-asthmatic groups were significantly younger than normal-weight asthmatics. The difference in the proportions of Hispanics and males, or in the mean height, across categories of obesity and asthma did not reach statistical significance. Overall, 30% of the sample was morbidly obese (BMI > 99th percentile). The proportion of morbid obesity did not vary by gender or ethnicity. No differences in severe obesity were found between obese asthmatics and obese non-asthmatics.

As shown in Table 1, FEV₁/FVC ratio was significantly lower among obese asthmatics ($p<0.01$) as compared to normal-weight non-asthmatics. Similarly FEF_{25-75%} was significantly lower among the obese ($p=0.02$) and normal-weight asthmatics ($p<0.005$) than normal-weight non-asthmatics. Mean FVC and FEV₁ were not found to be significantly different between the study groups. The pulmonary function variables were also not different between the morbidly obese and non-morbidly obese.

Asthma severity did not differ ($p=0.6$) between obese and normal-weight asthmatics. Among the obese asthmatics, 51.5% had intermittent asthma, 18% had mild persistent, 30% had moderate persistent, and 0.5% had severe persistent asthma. In the normal-weight asthmatic group, 36.8% had intermittent, 26.4% had mild persistent, and 36.8% had moderate persistent asthma.

6 Minute Walk Test

The variables obtained during the 6MWT are summarized in Table 2. The 6MWD was shorter among the obese asthmatics (441.8 ± 60.9) than both normal weight asthmatics (481.1 ± 83.8) ($p=0.05$) and normal weight non-asthmatics (477.1 ± 55.3) ($p=0.02$). However, there was no difference between the obese asthmatics and obese non-asthmatics

(456.7±51.2)(p=0.28). The 6MWD did not differ between the morbidly obese and their non-morbidly obese counterparts.

Heart rate at baseline was higher among obese asthmatics than normal-weight asthmatics (p<0.0001), obese non-asthmatics (p<0.01) and normal-weight non-asthmatics (p<0.005) at baseline. Heart rate at completion of 6MWT remained significantly higher in obese asthmatics compared to normal-weight asthmatics (p<0.0001) and non-asthmatics (p<0.005). There was no difference in the initial or the final Borg dyspnea index between the four study groups.

Association of 6MWD with demographics, anthropometrics, and spirometry

The 6MWD was significantly lower among the African Americans (442.9±51) compared to Hispanics (473.2±65.6) (p=0.007) but did not differ between males (462.2±69.2) and females (460.9±58.3) (p=0.91). There was no association of the 6MWD with age or height for the total sample or between the study groups.

The association of 6MWD with BMI and FEV₁ was compared by asthma and obesity status. As shown in Figure 1, while the 6MWD decreased with increasing BMI (Figure 1a) and increased with increasing FEV₁ (Figure 1b), these associations did not differ by the presence or absence of asthma. When dichotomized by presence or absence of obesity, among obese adolescents, the 6MWD decreased with increasing BMI but did not change with FEV₁ (Figure 2a). On the other hand, among normal weight adolescents the 6MWD increased with increasing FEV₁ but did not change with increase in BMI (Figure 2b).

In keeping with the results shown in Figure 2, while there was a significant positive correlation between FEV₁ and the 6MWD among the normal-weight asthmatics (r=0.45, p=0.04) and non-asthmatics (r= 0.4, p=0.03), there was no correlation found among the obese asthmatics (r=0.07, p=0.7) and obese non-asthmatics (r=0.22, p=0.1). Conversely, while the 6MWD negatively correlated with BMI among obese asthmatics (r= -0.35, p=0.04) and obese non-asthmatics (r= -0.29, p=0.05), no association was present in the normal-weight asthmatics (r=0.08, p=0.7) and non-asthmatics (r=0.1, p=0.6). There was no association between 6MWD and FEV₁/FVC ratio or percent predicted FEF_{25-75%} for the entire sample or for each study group. The 6MWD was not also associated with the initial or final heart rate or the initial or final Borg index score in the entire sample or within each study group.

Given these univariate associations of 6MWD with African American ethnicity, percent predicted FEV₁ and BMI, multivariate linear regression analysis was conducted. The results are shown in Table 3. For the entire study sample, when adjusted for age, gender, height and using Hispanics as the reference group, BMI, FEV₁ and African American ethnicity were significantly determinants of 6MWD. These variables explained 22% of the variability of the 6MWD. While a unit increase in BMI was associated with shorter 6MWD, unit increase in FEV₁ was associated with greater 6MWD. African Americans walked 32.1 meters (95%CI 10.7–53.4, p 0.004) less than Hispanics. On stratifying the model by obesity, the relationship observed in univariate analysis persisted. Among the obese participants, BMI, rather than FEV₁, was a significant predictor of 6MWD. Among normal-weight participants, FEV₁ rather than BMI, was a significant predictor of 6MWD. The 6MWD covered by obese African Americans was 33.8±12.2 meters less than that covered by obese Hispanics (p<0.005). There was no difference in the 6MWD between the two ethnic groups in the normal weight group.

Discussion

Among urban minority adolescents, we found that obese asthmatics had decreased functional exercise capacity as they covered the shortest 6MWD when compared to adolescents with obesity or asthma alone or neither condition. In elucidating the individual associations of asthma and obesity with 6MWD, we found that the association of 6MWD with FEV₁ as well as with BMI differed by obesity status but not by asthma status. While 6MWD inversely correlated with BMI only in the obese participants, it directly correlated with FEV₁ only among the normal-weight participants. There was no association between 6MWD and FEV₁ among the obese participants, both in those with and without asthma. This lack of association of 6MWD with FEV₁ among the obese participants remained even after adjusting for age, gender, and height. By comparing obese asthmatic adolescents with those with obesity or asthma or neither, we were able to investigate the individual role of each condition on functional exercise capacity. These findings suggest that while functional exercise capacity was primarily associated with pulmonary function among the normal weight adolescents, it was associated with adiposity among the obese adolescents, irrespective of the presence or absence of asthma.

We also found that in our study population, African Americans walked a shorter distance than Hispanics. After adjusting for age, gender, BMI and FEV₁, this association remained significant only among the obese adolescents. There was no difference between the two ethnic groups in age, gender, height or pulmonary function testing. However, the mean BMI was borderline higher among African Americans than Hispanics suggesting that the differences in the 6MWD may indeed be due to the differences in BMI, in keeping with findings reported by Drinkard et. al.²⁹

Our findings confirm and extend those of prior studies where BMI was the primary predictor that was inversely related to functional exercise capacity among obese adolescents.^{26,29,30} We demonstrate that this association is present among obese asthmatic adolescents as well. As reported by Santuz et. al¹⁸, we did not find an association between functional exercise capacity and asthma severity or FEV₁ among obese asthmatic adolescents.

Asthmatic children are reported to be less active¹⁴ with the decrease in physical activity setting in early in life as demonstrated in an urban Head Start cohort.¹³ Although poor asthma control, and poor conditioning³¹ and physical fitness¹¹ are potential explanations for this sedentary lifestyle, objective evaluation with maximal exercise testing did not demonstrate a difference in the peak oxygen consumption between children with and without asthma.¹⁸ Maximal oxygen consumption was found to correlated with perceived ability of physical activity but not with asthma severity.²⁰ Similarly a study among urban children demonstrated generalized deconditioning among all asthmatics, irrespective of their BMI.³¹ Utilizing the 6MWT among urban obese asthmatic adolescents, our findings corroborate those found in younger children who underwent maximal exercise testing. In keeping with the lack of association with asthma severity in these studies^{18,20}, we found a larger association of functional exercise capacity with BMI than with FEV₁ among obese asthmatic adolescents. Our findings differ from those reported among preschool children where wheezing was directly correlated with physical activity.¹³ These differences suggest that poor exercise ability in younger years due to lower airway obstruction and airway reactivity may lead to the establishment of sedentary behaviors associated with weight gain¹³ among obese asthmatics. However, these patterns do not occur in all asthmatics as seen among our adolescent population. While exercise limitation among obese adolescents was primarily associated with BMI, that among normal-weight adolescents was related to FEV₁. While it may be hypothesized that differences in asthma severity in early years may

explain the observed differences, longitudinal studies are needed to further explore this hypothesis.

Joyner et. al.³¹ reported physical limitation in the absence of exercise induced bronchospasm among a cohort of urban children suggesting that history taking alone may not be able to differentiate deconditioning from actual symptoms. In keeping with these results, the 6MWD covered by even the normal weight non-asthmatic adolescents in our cohort was shorter than that covered by their age matched peers³², suggesting generalized deconditioning in our entire study population. These findings suggest that by utilizing 6MWT in conjunction with spirometry, reported physical limitation in obese asthmatic adolescents can be investigated further. As both these investigations can be conducted in a primary care setting, obese adolescents with stable asthma can be educated on the primary cause of their exercise limitation. Parental perceptions in addition to the child's own perceived limitation¹⁴ have been associated with the decrease in physical activity among asthmatic children during early years. However, children themselves find exercise limitation associated with asthma to be stigmatizing.³³ Hence, we propose utilizing our reported association of functional exercise capacity with BMI but not with pulmonary function as an educational tool to help dissipate myths about the role of asthma in the child's perceived exercise limitation. By optimizing asthma control and incorporating normal exercise tolerance as a measure of asthma control, primary care providers can educate parents as well as children early in life to prevent the negative spiral of a sedentary life and limited exercise tolerance.

We recognize that 6MWT has not been routinely used to measure functional exercise capacity among children. However, recent studies^{26,29,34} have increasingly utilized it given the ease of its application in clinical settings. While correlating closely with the results of maximal exercise testing²⁵, it obviates the need for specialized testing equipment and trained personnel required for exercise testing. Our findings confirm those of prior studies and suggest that the 6MWT may be a useful tool for exercise capacity evaluation among children and adolescents.

We also recognize that 6MWD may be influenced by factors other than BMI and FEV₁. Height may influence the 6MWD by altering the stride length. Since there was no difference in the height across the four study groups, it likely did not play a substantial role in the differences observed in 6MWD in our study. Since obese individuals are known to walk slower, the pace of walking may also influence the 6MWD. While the mean distance covered in our four study groups as well as the mean heart rate was lower than that reported among normal children of the same age range³², suggesting de-conditioning, it is important to note that there are no ethnicity specific reference values for Hispanic and African American children, highlighting the need for reference values for patient populations most afflicted by obesity and asthma.

Obesity has been associated with altered chest wall compliance, likely due to adipose tissue deposition on the chest wall and abdominal cavity.³⁵ Differences in body fat distribution with higher waist circumference among Hispanics³⁶ has been reported. Further, waist circumference has been correlated with decreased pulmonary function³⁷ and increased severity of asthma. Although we did not find an association between FEV₁ and 6MWD among the obese adolescents in our study, it may be hypothesized that differences in other pulmonary function measures including chest wall and pulmonary compliance may play a role in the 6MWD.³⁸ Future studies investigating the association of 6MWD with lung volumes and compliance measures, in addition to spirometry, will facilitate an improved understanding of the link between obesity-associated asthma with 6MWD.

The lack of association between pulmonary function and 6MWD may also be influenced by our selection of well-controlled asthmatics with no exacerbation in the preceding 3 months. However, our findings are similar to those reported by investigators utilizing maximal exercise testing among asthmatics. Further, our selection of adolescents with asthma was based on physician diagnosis and was not associated with objective documentation of airway hyper-responsiveness. However, since all asthmatics had ER visits with or without hospitalizations for asthma exacerbations for several years prior to study participation, irrespective of obesity status, we do not believe that there was a misclassification bias based on our selection criteria. Moreover, we did not perform spirometry testing after completion of the 6 minute walk test, which could have elucidated exercise induced pulmonary function changes and hence differences between the four study groups, as recently reported in a Caucasian pre-pubertal population.³⁴ Further, the relatively small sample, particularly in the normal-weight asthmatic group, may have played a role in the borderline significance of some associations. Additionally, we did not do simultaneous maximal exercise testing and hence do not have detailed information on oxygen consumption and bronchoconstriction after exercise. However, given that the 6MWT has been more closely linked to ability to do daily activities and correlates well with maximal exercise testing²⁵, it may be easily applied in a primary care setting, thereby facilitating objective evaluation of exercise limitation among adolescents with asthma and obesity.

In summary, we found that the 6MWD correlated with measures of adiposity rather than pulmonary function indices among obese urban adolescents with asthma. These findings confirm those of prior studies where a lack of correlation was noted between asthma severity and exercise capacity, suggesting that an exercise plan should be part of the treatment of all obese teenagers, irrespective of their asthma status. Our findings, in context of earlier studies, also suggest that obese patients with asthma and their caregivers should be educated about the greater association of exercise tolerance with obesity rather than asthma. Given the high prevalence of de-conditioning among urban minority children³¹, the myth of asthma being associated with limited exercise tolerance should be dispelled, particularly in those with good asthma control to increase physical activity and thereby weight loss. Given the ease of administration, the 6 minute walk test in conjunction with pulmonary function may be applied in routine evaluation of adolescents with obesity and asthma to facilitate education and greater participation in physical activity.

Acknowledgments

This publication was made possible by the Michael I. Cohen, MD Fund for Adolescent Medicine and by the CTSA Grant UL1 RR025750 and KL2 RR025749 and TL1 RR025748 from the National Center for Research Resources (NCRR), a component of the National Institutes of Health (NIH), and NIH roadmap for Medical Research. Its contents are solely the responsibility of the authors and do not necessarily represent the official view of the NCRR or NIH.

The authors would like to thank the research associates; C. Andrade, D. Angeli, S. Decosta, A. Greenberg, T. Strauss and all the teenagers who participated in the study.

References

1. Ogden CL, Carroll MD, McDowell MA, Tabak CJ, Flegal KM. Prevalence of Overweight and Obesity in the United States, 1999–2004. *JAMA*. 2006; 295(13):1549–1555. [PubMed: 16595758]
2. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007–2008. *JAMA*. 2010; 303(3):242–249. [PubMed: 20071470]
3. www.census.gov.
4. Gilliland FD, Berhane K, Islam T, McConnell R, Gauderman WJ, Gilliland SS, Avol E, Peters JM. Obesity and the risk of newly diagnosed asthma in school-age children. *Am J Epidemiol*. 2003; 158(5):406–415. [PubMed: 12936895]

5. Gold DR, Damokosh AI, Dockery DW, Berkey CS. Body-mass index as a predictor of incident of asthma in a prospective cohort of children. *Pediatr Pulmonol*. 2003; 36:514–521. [PubMed: 14618644]
6. Ginde AA, Santillan AA, Clark S, Camargo CA Jr. Body mass index and acute asthma severity among children presenting to the emergency department. *Pediatr Allergy Immunol*. 2010; 21(3): 480–488. [PubMed: 19548965]
7. Figueroa-Munoz JI, Chinn S, Rona RJ. Association between obesity and asthma in 4–11 year old children in the UK. *Thorax*. 2001; 56(2):133–137. [PubMed: 11209102]
8. Chinn S. Concurrent trends in asthma and obesity. *Thorax*. 2005; 60(1):3–4. [PubMed: 15618573]
9. von Kries R, Hermann M, Grunert VP, von Mutius E. Is obesity a risk factor for childhood asthma? *Allergy*. 2001; 56(4):318–322. [PubMed: 11284799]
10. Chen AY, Kim SE, Houtrow AJ, Newacheck PW. Prevalence of Obesity Among Children With Chronic Conditions. *Obesity*. 2009; 18:210–213. [PubMed: 19521350]
11. Vahlkvist S, Pedersen S. Fitness, daily activity and body composition in children with newly diagnosed, untreated asthma. *Allergy*. 2009
12. Lucas SR, Platts-Mills TA. Paediatric asthma and obesity. *Paediatr Respir Rev*. 2006; 7(4):233–238. [PubMed: 17098637]
13. Firrincieli V, Keller A, Ehrensberger R, Platts-Mills J, Shufflebarger C, Geldmaker B, TP-M. Decreased physical activity among Head Start children with a history of wheezing: use of an accelerometer to measure activity. *Pediatr Pulmonol*. 2005; 40(1):57–63. [PubMed: 15858799]
14. Glazebrook C, McPherson AC, Macdonald IA, Swift JA, Ramsay C, Newbould R, Smyth A. Asthma as a barrier to children's physical activity: Implications for body mass index and mental health. *Pediatrics*. 2006; 118(6):2443–2449. [PubMed: 17142530]
15. Kattan M, Kumar R, Bloomberg GR, Mitchell HE, Calatroni A, Gergen PJ, Kercsmar CM, Visness CM, Matsui EC, Steinbach SF, Szeffler SJ, Sorkness CA, Morgan WJ, Teach SJ, Gan VN. Asthma control, adiposity, and adipokines among inner-city adolescents. *J Allergy Clin Immunol*. 2010; 125(3):584–592. [PubMed: 20226295]
16. 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(12):1036–1041. [PubMed: 14645968]
17. Spathopoulos D, Paraskakis E, Trypsianis G, Tsalkidis A, Arvanitidou V, Emporiadou M, Bouros D, Chatzimichael A. The effect of obesity on pulmonary lung function of school aged children in Greece. *Pediatr Pulmonol*. 2009; 44(3):273–280. [PubMed: 19208374]
18. Santuz P, Baraldi E, Filippone M, Zacchello F. Exercise performance in children with asthma: is it different from that of healthy controls? *Eur Resp J*. 1997; 10(6):1254–1260.
19. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS Statement: Guidelines for the Six-Minute Walk Test. *Am J Respir Crit Care Med*. 2002; 166:111–117. [PubMed: 12091180]
20. Pianosi PT, Davis HS. Determinants of physical fitness in children with asthma. *Pediatrics*. 2004; 113(3):e225–229. [PubMed: 14993581]
21. Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma. National Institute of Health: National Heart, Lung, and Blood Institute; 2007.
22. Epi Info Version 3.5.1. www.cdc.gov
23. Loeb JSBW, Feldstein JF, Koch BA, Munlin AL, Hardie WD. Acceptability and repeatability of spirometry in children using updated ATS/ERS criteria. *Pediatr Pulmonol*. 2008; 43(10):1020–1024. [PubMed: 18785259]
24. Hankinson JL, Odencrantz JR, Fedan KB. Spirometric Reference Values from a Sample of the General U.S. Population. *Am J Respir Crit Care Med*. 1999; 159:179–187. [PubMed: 9872837]
25. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med*. 2002; 166(1): 111–117. [PubMed: 12091180]
26. Borg GAV. Psycho-physical bases of perceived exertion. *Med Sci Sports Exerc*. 1982; 14(5):377–381. [PubMed: 7154893]

27. Morinder G, Mattsson E, Sollander C, Marcus C, UEL. Six-minute walk test in obese children and adolescents: reproducibility and validity. *Physiother Res Int*. 2009; 14(2):91–104. [PubMed: 19003813]
28. Paggiaro PL, Dahle R, Bakran I, Frith L, Hollingworth K, Efthimiou J. Multicentre randomised placebo-controlled trial of inhaled fluticasone propionate in patients with COPD. *Lancet*. 1998; 351:773–780. [PubMed: 9519948]
29. Drinkard B, McDuffie J, McCann S, Uwaifo GI, Nicholson J, JAY. Relationships between walk/run performance and cardiorespiratory fitness in adolescents who are overweight. *Physical Therapy*. 2001; 81(12):1889–1896. [PubMed: 11736623]
30. Andreasi V, Michelin E, Rinaldi AEM, Burini RC. Physical fitness and association with anthropometric measurements in 7 to 15 year-old school children. *J Pediatr (Rio J)*. 2010; 86(6):497–502. [PubMed: 21076797]
31. Joyner BL, Fiorino EK, Matta-Arroyo E, Needleman JP. Cardiopulmonary exercise testing in children and adolescents with asthma who report symptoms of exercise-induced bronchoconstriction. *J Asthma*. 2006; 43(9):675–678. [PubMed: 17092848]
32. Li AM, Yin J, Au JT, So HK, Tsang T, Wong E, Fok TF, Ng PC. Standard Reference for the Six-Minute-Walk Test in Healthy Children Aged 7 to 16 Years. *Am J Respir Crit Care Med*. 2007; 176:174–180. [PubMed: 17463419]
33. Chadwick S. The impact of asthma in an inner-city general practice. *Child Care Health Dev*. 1996; 22(3):175–186. [PubMed: 8735672]
34. Consilvio NP, Di Pillo S, Verini M, de Giorgis T, Cingolani A, Chiavaroli V, Chiarelli F, Mohn A. The reciprocal influences of asthma and obesity on lung function testing, AHR, and airway inflammation in prepubertal children. *Pediatr Pulmonol*. 2010; 45(11):1103–1110. [PubMed: 20672295]
35. Littleton SW. The impact of obesity on respiratory function. *Respirology*. 2012; 17(1):43–49. [PubMed: 22040049]
36. Messiah SE, Arheart KL, Lipshultz SE, Miller TL. Ethnic group differences in waist circumference percentiles among U.S. children and adolescents: estimates from the 1999–2008 national health and nutrition examination surveys. *Metab Syndr Relat Disord*. 2011; 9(4):297–303. [PubMed: 21466378]
37. Chen Y, Rennie D, Cormier Y, Dosman JA. Waist circumference associated with pulmonary function in children. *Pediatr Pulmonol*. 2009; 44(3):216–221. [PubMed: 19205050]
38. Dixon AE, Holguin F, Sood A, Salome CM, Pratley RE, Beuther DA, Celedón JC, Shore SA. An official American Thoracic Society Workshop report: obesity and asthma. *Proc Am Thorac Soc*. 2010; 7(5):325–335. [PubMed: 20844291]

Figure 1a

Figure 1b

Figure 1. Association of 6MWD with a) BMI and b) FEV₁ by asthma status

There was a negative correlation between BMI and 6MWD that did not differ by between asthmatics and non-asthmatics (Fig 1a). Similarly, there was a direct correlation between FEV₁ and 6MWD that was statistically significant among non-asthmatics but did not reach significance among asthmatics (Fig 1b).

Figure 2a

Figure 2b

Figure 2. Association of 6MWD with a) BMI and b) FEV₁ by obesity status

There was a negative correlation between BMI and 6MWD among the obese only; a similar association was not present in the normal-weight group (Fig 2a). Conversely, there was a direct correlation between FEV₁ and 6MWD in the normal-weight group but not in the obese group (Fig 2b).

Table 1

Comparison of demographic, anthropometric, and spirometry measures between the four study groups

Variable	Obese Asthmatic (n=33)	Normal-weight Asthmatic (n=18)	Obese Non-asthmatic (n=38)	Normal-weight Non-asthmatic (n=29)
Weight (kg)	105.5 ± 21.6	58.3 ± 10.8	107.2 ± 27.3	62.4 ± 11
Height (cm)	165.8 ± 9	162.3 ± 7.4	167.1 ± 8.5	164.9 ± 9.2
BMI	38.1 ± 5.4	21.9 ± 3	38.1 ± 7.6	22.8 ± 3
BMI z-score	2.5±0.4	0.3±0.8	2.3±0.4	0.4±0.9
Age (yrs)	15.2 ± 1.9*	16.3±2.4	15.8 ± 2.3 [#]	17.4 ± 2.1* [#]
Males (%)	44.1	36.8	29.6	16.1
Ethnicity (%Hispanics)	47.1	73.7	60.5	67.7
FVC (% pred)	98.2 ± 17.8	94.8 ± 15.2	96.9 ± 15.1	98 ± 12.5
FEV ₁ (% pred)	91 ± 16.3	87.9 ± 15.5	93.6 ± 14.4	96.2 ± 9.5
FEV ₁ /FVC	82.2 ± 7.7 [^]	82.1 ± 9.8	85.3 ± 5.6	86.6 ± 5.5 [^]
FEF _{25-75%} (% pred)	80.7 ± 26.4 ^{&}	76.7 ± 22.7**	91.6 ± 23	93.7 ± 16.4 ^{&***}

All continuous variables are reported as mean±SD and all categorical variables are reported as proportions (%)

The mean age of obese asthmatics (* p<0.001) and that of obese non-asthmatics (# p<0.01) was lower than that of normal-weight non-asthmatics.

Mean FEV₁/FVC among obese asthmatics was lower ([^] p<0.01) than normal-weight non-asthmatics.

Mean FEF_{25-75%} was lower among obese asthmatics ([&] p<0.02) and normal-weight asthmatics(** p<0.005) than normal-weight non-asthmatics.

Table 2

Comparison of 6MWT variables between the four study groups

Variable*	Obese Asthmatic (n=33)	Normal-weight Asthmatic (n=18)	Obese Non-asthmatic (n=38)	Normal-weight Non-asthmatic (n=29)
6MWD (meters)	441.8 ± 60.9 ^{\$^}	481.1 ± 83.8 ^{\$}	456.7 ± 51.2	477.1 ± 55.3 [^]
Heart Rate before 6MWT	84.6 ± 11.7 ^{**\$#}	70.9 ± 9.1 ^{**}	76.9 ± 10.3 ^{\$}	74.9 ± 9.6 [#]
Heart Rate after 6MWT	107.5 ± 16 ^{¶¥}	87.2 ± 16 [¶]	98.4 ± 15.2	92.9 ± 16.2 [¥]
Borg dyspnea index before 6MWT	0.44 ± 1.09	0.15 ± 0.47	0.18 ± 0.56	0.03 ± 0.12
Borg dyspnea index after 6MWT	1.27 ± 1.67	0.68 ± 0.85	1.17 ± 1.65	0.61 ± 0.85

* All variables are reported as mean±SD

Mean 6MWD covered by obese asthmatics were significantly lower than normal weight asthmatics (^{\$}p<0.05) and normal weight non-asthmatics ([^]p<0.01)

Mean heart rate before 6MWT was significantly higher among obese asthmatics as compared to normal weight asthmatics (^{**} p<0.0001), obese non-asthmatics (^{\$}p<0.01) and normal-weight non-asthmatics ([#] p<0.005)

Mean heart rate after 6MWT was significantly higher among obese asthmatics as compared to normal weight asthmatics ([¶]p<0.0001), and normal weight non-asthmatics ([¥]p<0.005).

Table 3Multiple linear regression for the association of 6 minute walk distance with BMI and FEV₁

Variable	All participants (n= 118) * (95% CI**, p value)	Obese (n= 71) (95% CI, p value)	Normal weight (n= 47) (95% CI, p value)
BMI	-1.84 (-3.01- -0.69, 0.002)	-2.76 (-4.77- -0.76, 0.008)	-1.62 (-8.4-5.19, 0.6)
Percent predicted FEV ₁	1.1 (0.33- 1.87, 0.005)	0.69 (-0.17- 1.56, 0.1)	1.87 (0.28- 3.45, 0.02)
Ethnicity	-32.1 (-53.4- -10.7, 0.004)	-33.8 (-58.15- -9.42, 0.007)	-33.6 (-77.37- 10.11, 0.12)

* denotes the unit change in the 6 minute walk distance for a unit change in BMI, FEV₁, and the difference between African American and Hispanic adolescents, with Hispanic adolescents as the reference group. was obtained by multivariate regression of the 6 minute walk distance for all participants and stratified by obesity status. The model included BMI or FEV₁ as primary independent variable and was adjusted for age, gender, height and ethnicity as potential confounders.

** 95% CI denotes the 95% confidence interval for the estimated