

OBESITY

The Association of Overweight and Obesity with Spirometric Values in Minority Children Referred for Asthma Evaluation

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Background. Overweight, obesity, and asthma are more prevalent in minority children; yet, the association of overweight and obesity with spirometric values in asthmatic minorities is not well characterized. **Objective.** To study the relationship between weight, ethnicity, and spirometric values in children referred for asthma evaluation to a large inner-city hospital in Bronx, NY. **Methods.** Retrospective review of spirometry done at the first pulmonary clinic visit of 980 asthmatic children, aged 7–20 years, was conducted. Linear regression analysis was performed to elucidate the association of overweight and obesity with pulmonary function among Whites, African Americans, and Hispanics compared with their normal weight counterparts. **Results.** More African Americans (58%) and Hispanics (65.4%) were overweight and obese than Whites (51.2%) ($p < .05$). Compared with their normal weight counterparts, percent forced expiratory volume in the 1st second (FEV₁)/forced vital capacity (FVC) ratio was lower in both overweight and obese African Americans (2.99%, $p < .05$ and 3.56%, $p < .01$, respectively) and Hispanics (2.64%, $p < .05$ and 2.36%, $p < .05$, respectively); these differences were found in obese (3.73%, $p < .05$) but not in overweight (0.68%, $p = .7$) Whites. **Conclusions.** FEV₁/FVC ratio was lower in both overweight and obese African American and Hispanic children, while this association was present only among obese Whites compared with their normal weight counterparts. These results suggest that spirometric measures of lower airway obstruction decrease with smaller weight increments in minority children when compared with White children. In the context of the higher prevalence of overweight and obesity among African Americans and Hispanics, our findings offer one potential explanation for increased asthma among minority children.

Keywords asthma, Body Mass Index, inner city, lung function test, pediatric

INTRODUCTION

An association between childhood obesity and asthma has been reported over the past decade (1–6). While the mechanisms explaining this association are unclear, impairment of pulmonary function has been proposed as a potential explanation. Forced vital capacity (FVC) and forced expiratory volume in the 1st second (FEV₁) increase, but FEV₁/FVC ratio decreases with increase in Body Mass Index (BMI) in obese asthmatic children (7, 8). Compared to asthmatics, the relationship between BMI and FVC, FEV₁, and mid expiratory flow rates (FEF_{25–75%}) in non-asthmatics has been variable (8–12), but decreased FEV₁/FVC ratio has been the one consistent finding among all these studies.

While both asthma and obesity disproportionately affect urban minorities including Hispanics and African Americans (1, 13, 14), there is a dearth of information on the patterns of pulmonary function among obese asthmatic minority children compared with their non-obese counterparts and with Whites. Ethnicity-specific deficits in spirometric indices have been reported; Hispanics and African Americans have lower mean FVC and FEV₁ than Whites

across the entire age range from 8 to 80 years (15). However, the independent association of overweight and obesity with pulmonary function among minority asthmatic children has not been well elucidated. By utilizing ethnicity-specific percent-predicted spirometric indices, we investigated the association of overweight and obesity with spirometric values in a large sample of children referred for asthma evaluation to a tertiary health care center. We hypothesized that overweight and obesity will be independently associated with augmented lower airway obstruction in African American and Hispanic children when compared with Whites.

MATERIALS AND METHODS

Study Population

Spirometry, demographic, and anthropometric data on 1870 asthmatic children from their first visits to the pulmonary clinic at the Children's Hospital at Montefiore, Bronx, NY between 1 January 2003 and 31 December 2007 were collected by retrospective chart review. This study was conducted with the approval of the Internal Review Board (IRB) at the Montefiore Medical Center and the waiver of informed consent was obtained.

Of the 1870 spirometries conducted on children with the diagnosis of asthma, 316 had other comorbidities, including

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scoliosis, sickle cell disease, rheumatological conditions, prematurity, and malignancy, and were therefore excluded from the study. Within the remaining 1554 asthmatic children, 474 records in which information on ethnicity was missing or was reported as mixed race/ethnicity were excluded. In addition, records from 34 children who were underweight (BMI < 5th percentile) and 66 children who were not able to complete the maneuver or who were less than 7 years of age were also excluded from the analysis.

Data from the remaining 980 children aged 7–20 years who had physician-diagnosed asthma and had ethnicity reported as African American, Hispanic, or White was analyzed. Height, weight, age, and gender were abstracted from the medical records. BMI was calculated for all children. The study sample was stratified into normal weight, overweight, and obese categories based on the BMI *z*-score calculated on the EPI Info Nutrition Module utilizing the weight and height obtained on the day of the pulmonary function testing (16). Those with BMI *z*-score <1.04 and ≥ -1.64 (5th to <85th percentile) were classified as normal weight, those with BMI *z*-score ≤ 1.64 and ≥ 1.04 (85th to 95th percentile) were classified as overweight, and those with BMI *z*-score of >1.64 representing >95th percentile were classified as obese.

Pulmonary Function Testing

Pulmonary function testing was performed on a VMax 229 spirometer (Sensormedics Corp., Yorba Linda, CA, USA) in accordance with the American Thoracic Society (ATS) guidelines (17). The spirometer was calibrated daily. A single respiratory therapist, who had received formal training in pulmonary function testing, performed all the tests. All children performed the maneuvers in a sitting position with a nose clip in place. The best effort of three completed maneuvers that met the criteria for both acceptability and reproducibility as per the ATS guidelines was retained for analysis (17). As the majority of subjects were African American or Hispanic, reference values developed from the National Health and Nutrition Examination Survey (NHANES) by Hankinson et al. (15) were applied to obtain

percent-predicted and percentage values of the spirometric indices. Percent-predicted values for FVC, FEV₁, and FEF_{25–75%} and percentage values for FEV₁/FVC ratio were included in the analysis (17).

Statistical Analysis

Demographic variables were compared between the three ethnic groups, Whites, African Americans, and Hispanics, and are reported as mean $\pm$ standard deviation (SD). The spirometric indices were compared between the three ethnic and three weight categories. These analyses were done using analysis of variance (ANOVA) with Bonferroni post hoc analysis and are reported as means with 95% confidence interval (CI). Chi-square test was used to compare the weight categories. All spirometric indices are normally distributed, as determined by the Shapiro–Francia normality test. To elucidate the independent association of the spirometric indices with ethnicity in each weight category, linear regression analysis was conducted, adjusting for gender. As spirometric percent-predicted values were used in the analysis and are therefore already adjusted for age and height, the linear regression model did not adjust for these variables. Furthermore, given the wide age range in the study sample, age was additionally analyzed as a dichotomous variable. The age groups analyzed were 7–11 years and 12–20 years. Statistical analysis was conducted on STATA 10 software (College Station, TX, USA) and significance was set *a priori* at 0.05.

RESULTS

Study Population

Table 1 summarizes the demographic and anthropometric data of 980 asthmatic children aged 7–20 years with BMI above the 5th percentile. There was no difference in the distribution of age, gender, and height between the three ethnic groups. There was also no difference within and between the age groups of 7–11 years and 12–20 years. However, there were more overweight and obese children

TABLE 1.—Comparison of the demographic and anthropometric variables between the ethnic groups.

	Whites <i>n</i> (%) 155 (16)	African Americans <i>n</i> (%) 417 (42)	Hispanics <i>n</i> (%) 408 (42)	<i>P</i> -value ^b
Age ^a (year)	11.73 $\pm$ 3.28	11.81 $\pm$ 3.34	11.57 $\pm$ 3.28	.58
Gender (M:F) 1:1.1 (525:459)	1:1.1 (83:73)	1:1.2 (224:194)	1:1.1 (218:192)	.99
Height ^a (cm)	149.5 $\pm$ 17.2	150.8 $\pm$ 16.0	148.9 $\pm$ 16.6	.22
BMI ^a	22.98 $\pm$ 6.42 ^{c,d}	25.63 $\pm$ 9.57 ^c	25.59 $\pm$ 9.09 ^d	<.01
BMI <i>z</i> -score ^a	1.044 $\pm$ 1.046 ^c	1.28 $\pm$ 1.14	1.39 $\pm$ 1.07 ^c	<.01
Weight status				.02
Normal weight (<i>n</i> = 389)	75 (48.4)	174 (41.6)	140 (34.3)	
Overweight (<i>n</i> = 159)	26 (16.8)	63 (15)	70 (17.2)	
Obese (<i>n</i> = 432)	54 (34.8)	180 (43.1)	198 (48.5)	

Notes: ^aValues expressed as mean $\pm$ SD.

^b*P*-value obtained from ANOVA or chi-square test.

Compared with Whites, BMI was significantly higher among African Americans (^c*p* = .005) and Hispanics (^d*p* = .006). There was no difference between African Americans and Hispanics (*p* = 1.0). Similarly, mean BMI *z*-score was higher among Hispanics than Whites (^c*p* < .01). Although higher among African Americans, the difference with Whites (*p* = .062) did not reach statistical significance.

in the African American and Hispanic groups when compared with Whites ($p < .05$). Both Hispanics ($p < .01$) and African Americans ($p < .005$) had a higher average BMI than Whites. There was no difference in mean BMI ($p = 1$) or BMI z-score ($p = 0.5$) between Hispanics and African Americans.

Pulmonary Function Analysis among Ethnic Groups

As shown in Figure 1, the overall pulmonary function was well preserved in all the three ethnic groups with FVC, FEV₁, and FEV₁/FVC ratio being within the normal range. However, mean percent-predicted FVC, FEV₁, and FEF_{25-75%} and percent FEV₁/FVC ratio were significantly different across the three ethnic groups. Compared with Whites, percent-predicted FVC was 4.8% lower in Hispanics (95% CI: 1.9–7.8) and percent FEV₁/FVC ratio was 2.3% lower in African Americans (95% CI: 0.7–3.8). Percent-predicted FEV₁ was 4.5% lower among African Americans (95% CI: 1.3–7.7) and 6.2% lower in Hispanics (95% CI: 3–9.4), respectively. Similarly, compared with Whites, FEF_{25-75%} was 11.3% lower in African Americans (95% CI: 6.6–15.9) and 9.5% lower in Hispanics (95% CI: 4.9–16.6). Both FEV₁ ($p = 0.45$) and FEF_{25-75%} ($p = 0.98$) did not differ between African Americans and Hispanics. These findings among the three ethnic groups persisted when age was stratified into groups of 7–11 years and 12–20 years.

Association of BMI with Pulmonary Function among Ethnic Groups

Given the differences in both pulmonary function indices and the proportion of overweight and obese in African Americans and Hispanics when compared with Whites, we compared spirometric indices between the ethnic

groups for each weight category: normal weight, overweight, and obese. The results are summarized in Figure 2. In the normal weight category, mean percent-predicted FVC ($p < .05$), FEV₁ ($p < .01$), and FEF_{25-75%} ($p < .005$) were significantly different between the three ethnic groups. When compared with Whites, percent-predicted FVC was 5.5% lower (95% CI: 1.2–9.9) and percent-predicted FEV₁ was 7% lower (95% CI: 2.5–11.6) in Hispanics. Percent-predicted FEF_{25-75%} was 9.6% lower in Hispanics (95% CI: 1.2–18.0) and 11.3% lower in African Americans (95% CI: 4.7–17.9). Similarly, in the overweight group, a significant difference was observed in FEV₁ ($p < .005$) and FEF_{25-75%} ($p < .01$) between the three ethnic groups. While percent-predicted FEV₁ was 12.7% lower in overweight Hispanics (95% CI: 5.2–20.3) compared with Whites, the difference between Whites and African Americans reached borderline significance (9.2%, 95% CI: 1.5–16.9). Percent-predicted FEF_{25-75%} was 17.4% lower in overweight African Americans (95% CI: 4.9–29.9) and 19% lower in Hispanics (95% CI: 6.7–31.3) than Whites. Finally, in the obese category, no significant differences were found between the ethnic groups for any of the spirometric variables. Percent-predicted FVC was higher and percent FEV₁/FVC was lower in obese African Americans and Hispanics compared with their normal weight groups. No difference was observed between normal weight and overweight African Americans and Hispanics in any of the spirometric indices.

To elucidate whether these interethnic differences in pulmonary function were primarily due to ethnicity or due to differences in their weight status, multivariate analysis was done, adjusting for gender. The normal weight group served as the reference group. Age and height were not included in the model since the percent-predicted formulas include an adjustment for age and height. The results are summarized in Table 2. While percent-predicted FVC was 5.77% higher among obese African Americans (95% CI: 2.34–9.2) and 6.4% higher among obese Hispanics (95% CI: 2.92–9.87) compared with their normal weight counterparts, it reached borderline significant among obese Whites (5.17%, 95% CI: –0.11–10.5). Percent-predicted FEV₁ was 8.69% higher in overweight Whites (95% CI: 1.25–16.1) than normal weight Whites while the difference between overweight African Americans and Hispanics and their normal weight counterparts did not reach statistical significance. Percent-predicted FEV₁ was 4.21% higher in obese African Americans (95% CI: 0.40–8.03) and 4.43% higher in obese Hispanics (95% CI: 1.09–7.96) than their normal weight groups. Compared with the normal weight group, the FEV₁/FVC ratio was 3.73% lower only among obese Whites (95% CI: –6.85 to –0.62) but not in the overweight category ($\beta = -0.68$, 95% CI: –3.36 to 4.71). Percent FEV₁/FVC ratio was 2.99% (95% CI: –6.04 to –0.15) lower in overweight and 3.56% (95% CI: –5.75 to –1.35) lower in obese African Americans. Similarly FEV₁/FVC ratio was 2.64% (95% CI: –5.28 to –0.11) lower in overweight and 2.36% (95% CI: –4.38 to –0.35)

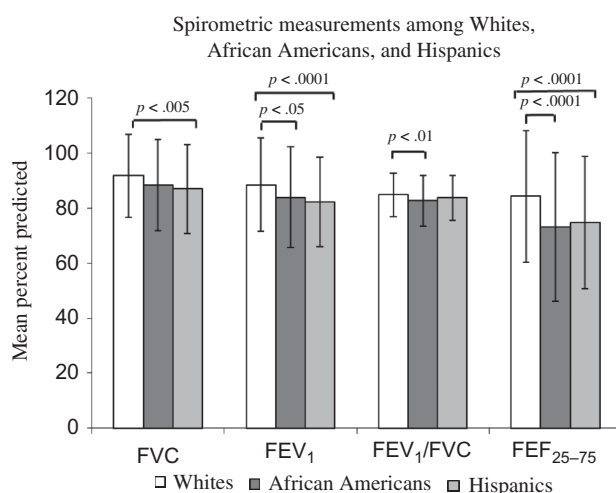


FIGURE 1.—Comparison of spirometry variables between White, African American and Hispanic asthmatic children. Spirometry variables reported as mean $\pm$ SD of percent-predicted values except for FEV₁/FVC, which is reported as a percentage. Compared with Whites, Hispanics had lower FVC ($p < .005$) and FEV₁ ($p < .0001$), while African Americans had lower FEV₁ ($p < .05$) and FEV₁/FVC ratio ($p < .01$). Also, compared with Whites, African Americans and Hispanics had lower FEF_{25-75%} ($p < .0001$ and $p < .0001$, respectively).

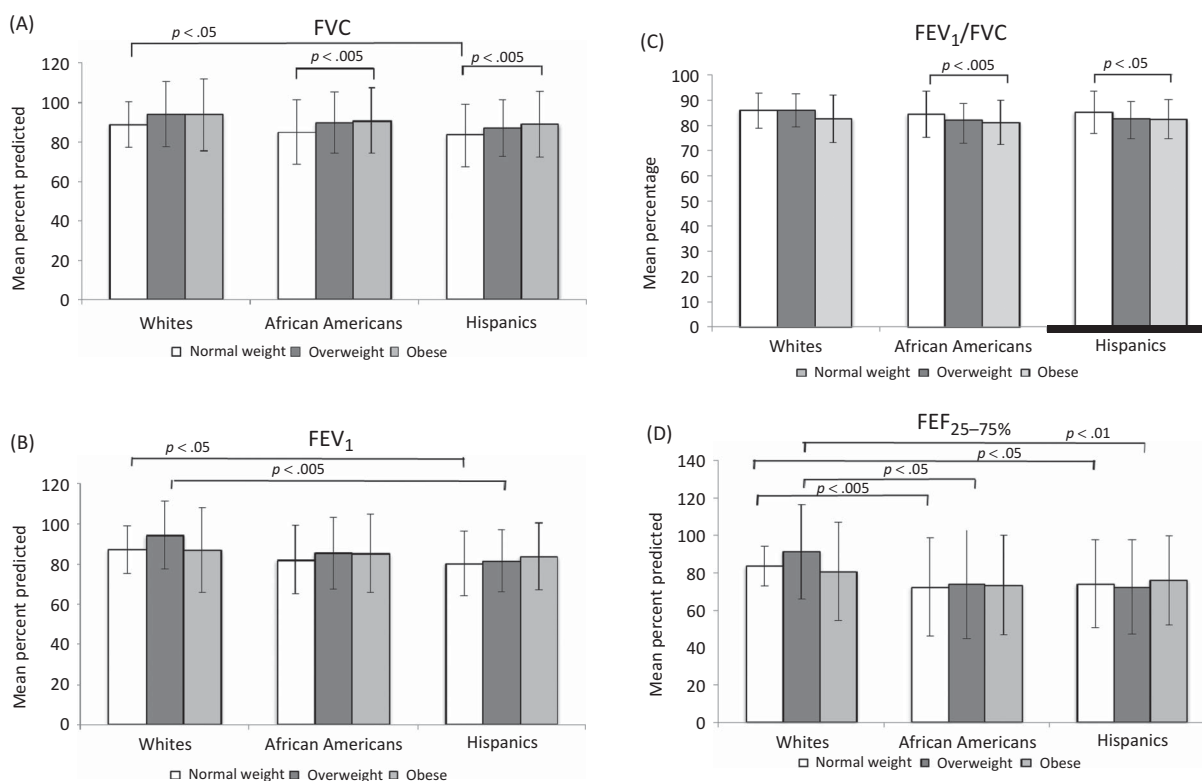


FIGURE 2.—Association between Spirometric Variables and BMI by Ethnicity. Spirometric variables reported as mean $\pm$ SD of percent predicted except for FEV₁/FVC, which is reported as a percentage. (A) Normal weight Hispanics had lower FVC than Whites. Obese African Americans and Hispanics had a higher FVC than their normal weight groups. (B) Both normal weight and overweight Hispanics had lower FEV₁ than weight matched Whites. (C) Percent-predicted FEV₁/FVC was lower in obese African Americans and Hispanics compared with their normal weight groups. (D) Compared with normal weight Whites, FEF_{25-75%} was lower in both normal weight Hispanics and African Americans. Compared with overweight Whites, FEF_{25-75%} was lower in both overweight Hispanics and African Americans.

TABLE 2.—Ethnicity-specific effect of overweight and obesity on spirometric indices among asthmatic children.

	Overweight (<i>n</i> = 159)				Obese (<i>n</i> = 432)		
Variables	β^a	95% CI	<i>P</i> -value		β^a	95% CI	<i>P</i> -value
FVC				FVC			
Whites (<i>n</i> = 26)	5.97	−0.87, 12.8	.09	Whites (<i>n</i> = 54)	5.17	−0.11, 10.5	.06
African Americans (<i>n</i> = 63)	4.65	−0.12, 9.41	.06	African Americans (<i>n</i> = 180)	5.77	2.34, 9.20	<.01
Hispanics (<i>n</i> = 70)	3.83	0.72, 8.39	.01	Hispanics (<i>n</i> = 198)	6.40	2.92, 9.87	<.0001
FEV ₁				FEV ₁			
Whites	8.69	1.25, 16.1	<.05	Whites	−0.002	−5.74, 5.74	.99
African Americans	3.17	−2.15, 8.50	.24	African Americans	4.21	0.40, 8.03	<.05
Hispanics	1.49	−3.13, 6.12	.53	Hispanics	4.43	1.09, 7.96	<.01
FEV ₁ /FVC				FEV ₁ /FVC			
Whites	−.68	−3.36, 4.71	.74	Whites	−3.73	−6.85, −0.62	<.05
African Americans	−2.99	−6.04, −0.15	<.05	African Americans	−3.56	−5.75, −1.35	<.005
Hispanics	−2.64	−5.28, −0.11	<.05	Hispanics	−2.36	−4.38, −0.35	<.05
FEF _{25–75}				FEF _{25–75}			
Whites	9.21	−1.51, 19.9	.09	Whites	−2.37	−10.64, 5.90	.57
African Americans	1.77	−6.08, 9.63	.66	African Americans	0.99	−4.66, 6.65	.73
Hispanics	−1.74	−8.57, 5.08	.61	Hispanics	3.14	−2.05, 8.34	.24

Notes: Percent-predicted values of FVC, FEV₁, and FEF_{25-75%} or percentage values of FEV₁/FVC were compared between weight categories within each ethnicity. The normal weight group within each ethnicity served as the reference group.

^a β denotes the difference in each spirometry index (percent predicted or percent) between the overweight or obese groups, and the normal weight group, for each ethnicity. β was obtained by multivariate linear regression of the spirometric variables in the overweight and obese categories, adjusting for gender.

lower in obese Hispanics compared with their normal weight counterparts. Among all three ethnic groups, there was no statistical significant difference in FEF_{25-75%} when BMI z-score was stratified into overweight or obese

groups. To further elucidate whether these observed inter-ethnic differences in pulmonary function were due to an interaction between ethnicity and weight, additional linear regression analysis conducted with the interaction

term race*BMI for Hispanics and African Americans showed that there was no statistical significance of interaction between race and BMI on pulmonary function indices. The addition of age as a dichotomous variable in the multivariate analysis did not influence the association of overweight and obesity with pulmonary function indices.

We also found that gender remained a significant predictor of pulmonary function indices in the multivariate analysis. For every unit increase in BMI z-score, compared with boys, girls of all ethnicities had higher FEV₁/FVC ratio. It was 4.29% higher in Whites (95% CI: 1.43–7.15), 2% higher in African Americans (95% CI: 0.39–4.03), and 4.49% higher in Hispanics (95% CI: 2.67–6.3). Hispanic girls had percent-predicted FVC 4.95% higher (95% CI: 1.83–8.07), percent-predicted FEV₁ 5.63% higher (95% CI: 2.46–8.8) and percent-predicted FEF_{25–75%} 8.48% higher (95% CI: 3.80–13.16) than Hispanic boys.

DISCUSSION

In a referred population of inner-city children with physician-diagnosed asthma, we found that both African American and Hispanic children had lower spirometric indices than Whites. African Americans had lower percent-predicted FEV₁ and FEF_{25–75%} and lower FEV₁/FVC ratio when compared with Whites, while Hispanics had lower percent-predicted FVC, FEV₁, and FEF_{25–75%}. These differences were accentuated in the presence of overweight and obesity. While both African American and Hispanic overweight as well as obese children had lower FEV₁/FVC ratio when compared with their normal weight counterparts, this association was present only among the obese Whites. Our findings suggest that smaller weight increments among Hispanics and African Americans, such as from normal weight to overweight, are associated with a significant decrease in measures of lower airway obstruction, whereas these differences are associated with greater weight increments among Whites.

Our findings of higher FVC and FEV₁ and lower FEV₁/FVC with increasing BMI are consistent with those previously reported (7, 9, 11, 12, 18); particularly with those of the Childhood Asthma Management Program (CAMP) in which the study population, like ours, included Whites, African Americans, and Hispanics (7). Our findings extend these results by identifying an accentuation in lower airway obstruction with smaller weight gains among minority populations. However, there are certain differences in our findings when compared with those of Tantisira *et al.* Compared to a multicenter trial, ours was a referral sample from a single center with a higher number of Hispanic and African Americans and included information on adolescents as well. In addition, we studied BMI as a continuous as well as a categorical variable utilizing established cut-offs of overweight and obese, which elucidated ethnicity-specific association of BMI with pulmonary function. Further, mean BMI in our ethnic groups was higher than the

children included in the CAMP study. Given these differences in study populations, contrary to the findings in the CAMP study, we found that there was indeed a threshold effect of BMI that differed by ethnicity.

Similar to previous studies (7, 9, 18, 19), we found gender-specific differences in the association of obesity with pulmonary function in asthmatic children. FEV₁/FVC ratio was higher among girls of all ethnicities. We also found that while FEF_{25–75%} was lower in African Americans and Hispanics compared to Whites and in the normal weight category as well as overweight category in keeping with the ethnicity-related differences (15), this difference did not persist on multivariate analysis by obesity status. These findings suggest that presentation of lower airway obstruction among the overweight and obese may not be primarily due to the alteration of airflow in the medium-sized airways. Adult studies have demonstrated differences in expiratory reserve volume and functional residual capacity (FRC) in obese individuals (20). Given the role that FRC plays in maintaining airway caliber during the respiratory cycle, changes in FRC in the setting of weight gain alter airway smooth muscle contractility and increase airway hyper-responsiveness (20). We recently demonstrated that decrease in FRC among obese asthmatic children is present as early as pre-adolescence (21). The degree to which changes in FRC play a role in the alteration of FEV₁/FVC when compared with FEF_{25–75%} among obese asthmatics needs further investigation.

The observed differences in these spirometric indices among Whites, African Americans, and Hispanics are likely multifactorial. Both Hispanics and African Americans have been reported to have lower spirometric indices when compared with Whites due to inherent differences in trunk to leg ratio of subjects with similar height, age, and gender (15, 22). Furthermore, in addition to the higher prevalence of obesity among minorities (23, 24), Hispanic and African American children and adolescents have been found to have higher waist circumferences than non-Hispanic Whites (25). Since waist circumference inversely correlates with pulmonary function (26) and directly correlates with asthma severity (27), the pulmonary function differences in our study may potentially be explained by ethnic differences in body habitus and truncal fat distribution.

The association of inflammation with pulmonary function among obese asthmatics has been less well studied. An inverse association between elevated CRP and FEV₁ has been reported in adults (28) and we found an inverse association between T cell-mediated inflammation and FEV₁/FVC ratio (21), but no association with waist circumference or waist hip ratio among pre-adolescent minority children (21). This suggests that obesity-mediated inflammation rather than mechanical fat load alone may be mediating the relationship of pulmonary function with obesity among children. Furthermore, genome-wide association studies have found single nucleotide polymorphisms in genes coding for inflammatory cytokines in asthmatics and linked them

with FEV₁/FVC ratio (29). Hence, genetic variations may potentially modulate the effect of obesity-associated, asthma-driven inflammation on pulmonary function in the different ethnic groups (30–32).

Other coexisting medical conditions including gastroesophageal reflux disease (GERD) (33) and atopy (34) may have additionally influenced pulmonary function in our cohort. Given that our study is retrospective with data abstraction done by chart review, presence of GERD was not routinely documented in the medical records. Given the high prevalence of GERD among overweight and obese individuals and its association with airway reactivity, its role in the observed pulmonary function abnormalities cannot be excluded. Similarly, evaluation for allergen sensitization was also not routinely done on all asthmatics. However, since obesity-associated asthma is non-atopic in nature (21, 35, 36), the extent to which atopy may influence pulmonary function in normal weight children may differ from that in overweight and obese children.

Further, low socioeconomic status is known to play a role in asthma severity and control (37) and thereby on pulmonary function tests. Over two-thirds of the Bronx population are residing in areas with over 20% poverty (38) and 40% of all children residing in the Bronx live in household below the poverty level (39). Lower socioeconomic status is associated with poor dietary habits (40) and higher rates of adult smokers (41) thereby increasing exposure to passive smoke among children (42, 43). While “current smoking” among residents of New York City was lower than the general population (<10%), that among the Bronx residents was 22% (44), closer to the national average of 22.1% in Whites and 21.3% in African Americans. However, ethnic differences in current smoking prevalence also vary based on the data source (45), limiting its use as a predictor variable in multivariate analysis conducted in this study. Additional environmental exposures including poor housing (46), extensive indoor allergen exposure (47, 48) and parental stress (49) associated with caring for an asthmatic child among residents of inner-city urban neighborhoods can independently influence asthma control and thereby pulmonary function testing. While the contribution of these factors toward poor asthma control and increased asthma severity has been well established, the extent to which they play a role in increasing disease severity and affecting pulmonary function among asthmatic children with overweight and obesity warrants additional investigation.

Our results and those of prior studies raise the question about the temporal relationship between asthma and obesity. Epidemiological studies among adults suggest that obesity precedes asthma in individuals with obesity-associated asthma (20, 43); however, this relationship is less evident among children with obesity and asthma (50). Given the early onset of asthma and of obesity in urban minority children (37), it is important to elucidate the initiating disease process in children to implement prevention and early therapeutic strategies to stem the high disease burden found among obese asthmatics (51).

Our study has certain limitations, primarily those associated with retrospective data analysis. Our cohort had a physician-diagnosis of asthma with no objective documentation of airway reactivity such as use of methacholine challenge. For similar reasons, we were unable to evaluate for such factors as GERD, atopy status, family history of asthma, or environmental exposures, which may additionally influence pulmonary function indices. Given the cross-sectional nature of the study, we were also not able to account for the severity and duration of asthma, or the duration of preventative medication use, particularly in light of the well-preserved pulmonary function indices in the study sample. Although inhaled steroid use is reported to be suboptimal in urban minority children (52), obesity is also known to modulate responsiveness to steroids (53), limiting the inferences that can be drawn between ethnicity-specific percent inhaled steroid use and pulmonary function testing in our cohort. We also did not have measures of distribution of body fat such as waist circumference which has been associated with greater effect on pulmonary function than BMI alone (27).

Furthermore, since we relied on self-reported identification of ethnicity, a large group of children and adolescents, who had missing ethnicity identification or had identified themselves as mixed ethnicity were excluded from the analysis. Additionally, there were fewer Whites in our study sample compared to Hispanics and African Americans which may have resulted in a lack of power for observing associations between overweight status and measures of lower airway obstruction in that subpopulation. Although the CAMP study had a higher proportion of Whites, similar details on influence of ethnicity on association of BMI categories with spirometric indices are not available. Additionally, we did not have a comparison group of non-asthmatic children that would have helped to further clarify the role of both obesity and asthma on pulmonary function.

We analyzed percent-predicted values rather than absolute values of each spirometry index. Given the wide age range in our study and the change that occurs in spirometry in these years (15), it was of higher clinical relevance to analyze percent-predicted values since they were already adjusted for differences in age and height. However, we were concerned that the NHANES prediction equations for Hispanics were based on norms developed in Mexican-Americans, and that those norms might not apply to the Hispanic population of the Bronx, which is largely Puerto Rican and Dominican. Therefore, as sensitivity analyses, we recalculated the percent-predicted values for Hispanic study participants using the NHANES prediction equations for African Americans and found little difference from the results achieved and reported in this study using prediction equations for Hispanics. A second sensitivity analysis found similar results when using the prediction equations for Whites (data not shown). We are therefore confident that our results are not an artifact of improper norming of percent-predicted values.

In conclusion, we found that decrease in FEV₁/FVC occurred with lower degrees of weight gain among the

minority populations when compared with Whites. Given our relatively large sample size composed of asthmatic children, we have been able to further elucidate the relationship between pulmonary function, ethnicity, and obesity among urban minority asthmatic children. These findings are important in light of the well-documented high prevalence of both obesity and asthma, as well as disparities in asthma severity in minority asthmatic children (37, 54, 55) and offer one potential explanation for the higher prevalence and severity of asthma in these ethnic minority groups. Yet, these findings have also been reported for other ethnic groups. This suggests that alteration in pulmonary function with weight gain alone does not completely explain the increased prevalence of asthma associated with obesity among the inner-city minority pediatric population. Further investigation of other potential mechanistic pathways such as the role of inflammation, genetic variability, and patterns of adiposity and their influence on pulmonary function will help facilitate a better understanding of the phenomenon of obesity-associated asthma among minority children. Future longitudinal prospective studies with similar number of participants of each ethnicity are needed to confirm our findings, to further elucidate the influence of ethnicity and define the temporal association between asthma and obesity among children.

DECLARATION OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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