

Clinical Study

Measures of Obesity Associated with Asthma Diagnosis in Ethnic Minority Children

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Objective. The study objective was to examine relationships between different body size measurements and asthma in ethnic minority children. *Methods.* We used data from a community-based study of 505 children aged 6-to-8 years old to study the association of percent body fat, fat distribution, and BMI percentile with asthma diagnosis. Poisson regression models were used to compute prevalence ratios (PRs) for sex-specific quintiles of the body fat measures on the main outcome of asthma. *Results.* When comparing the highest quintile of each body fat measure to the combined lowest two quintiles, higher body mass index percentile, percent body fat, and waist circumference all were associated with a higher likelihood of physician-diagnosed asthma (PR = 1.63 (95% CI 1.12–2.39), 1.50 (95% CI 1.02–2.21), and 1.56 (95% CI 1.04–2.34), resp.). *Conclusions.* This study found a significant association between increased body size and asthma diagnosis, regardless of the measurement examined.

1. Introduction

Asthma is a chronic, inflammatory lung disease characterized by symptoms of cough, wheezing, shortness of breath, and chest tightness that occur in paroxysms and are usually related to specific triggering events. Asthma in children, estimated to cost \$3.2 billion per year, accounts for 14 million missed school days annually and is the third-ranking cause of hospitalization among those younger than 15 years of age [1]. The prevalence of childhood asthma has increased dramatically over the past few decades in the United States [2]. Many factors have been proposed to explain increasing asthma rates, including genetic, environmental, and socioeconomic factors.

There has been a growing interest in the hypothesis that obesity contributes to the increased prevalence of asthma. The prevalence of childhood obesity is also increasing at alarming rates for children of all ages [3]. Obesity is a known risk factor for diabetes, heart disease, hypertension, and certain cancers. Evidence is now also building for an

association between asthma and obesity [4, 5]. A recent meta-analysis of the effect of high body weight during childhood on subsequent development of asthma estimated that those with high body weight have a future risk of asthma equal to 1.5 times the future risk of children without high body weight (95% CI for RR 1.2 to 1.8) [6]. This analysis also suggested that over 100,000 American children from age 5 to 14 suffer from asthma each year as a result of being overweight.

Previous asthma obesity association studies have used body mass index (BMI) as a measure of obesity. BMI is calculated by dividing the weight measurement (expressed in kilograms) by the square of the height (expressed in meters). BMI is a proxy measure for adiposity and often used clinically because it is easy to measure. Problems with use of BMI as a marker of obesity are well described [7]. One issue is uniform application of BMI standards across different races. In general, black children tend to have relatively less body fat, and Mexican American children tend to have relatively more body fat, compared with white children with the same BMI

[8]. Percent body fat values associated with elevated BMI also vary by age and gender (higher in peripubertal males than younger or older males and higher in females than males) [9]. In addition, for equivalent BMI, those with central obesity have greater body fatness than those with peripheral obesity [10].

Accurate assessment of body fatness may be important in understanding the relationship between obesity and asthma. Obesity is now widely regarded as a state of chronic, low-grade systemic inflammation characterized by increased circulating leukocytes and increased serum concentrations of cytokines, cytokine receptors, chemokines, and acute phase proteins [11]. There is evidence that some of these substances released by adipocytes may play a role in asthma [12].

In addition to quantity of fat, distribution of fat may play a role in asthma. Adipose tissue in the chest and abdominal wall compress the thoracic cage, diaphragm, and lungs. In adults, upper fat distribution has been shown to be associated with significantly lower forced vital capacity and forced expiratory volume in one second [13]. Regular spontaneous breathing imposes forces on airway smooth muscle which helps keep airways open [14]. Since individuals with abdominal obesity breathe at higher frequencies but smaller volumes, the strain keeping airways open is decreased, and this predisposes toward airway constriction [11].

A few previous asthma obesity association studies have used other adiposity measures such as triceps skinfold thickness or bioelectrical impedance analysis and have had mixed results [15, 16]. Few studies have attempted to assess the role of fat distribution on asthma in children [17–19]; only one [17] concluded that there was no consistent relationship between these measures and intermediate asthma phenotypes. The purpose of this study was to examine the association between different measures of obesity and asthma diagnosis in ethnic minority children. We hypothesized that age- and gender-specific BMI percentile, body fat percentage, waist circumference, and waist-to-height ratio would be associated with reported asthma diagnosis.

2. Methods

2.1. Study Design and Participants. The Growing Up Healthy (GUH) study is a community-based epidemiologic study including 505 six to eight year old New York City children enrolled in 2004–2007. Female participants were recruited as part of a multicenter study in three U.S. cities to describe the assessment methods and maturation status for a cohort of girls [20]. Boys were recruited as part of a parallel study, Growing Up Healthy in East Harlem, which is examining the effects of the built environment, neighborhood characteristics and endocrine disrupting exposures on growth and development of East Harlem girls and boys [21]. Because one of the primary outcomes in a subset of the cohort is onset of puberty in girls, there are more girls ($n = 400$) than boys ($n = 105$) in the study. English- and Spanish-speaking children were recruited as per an institutional review board-approved protocol from an academic primary care pediatric practice, community health centers, and schools. When

collecting information from Spanish-speaking families, the questionnaire was administered in Spanish. In all cases, only persons knowledgeable about the child and family were asked to complete the questionnaire. Consent was obtained from the parents, and assent was obtained from the children. Children with endocrine disorders or other medical conditions that may be related to obesity were ineligible.

2.2. Measurements

2.2.1. Outcome Measurement. The main outcome was parental report of physician diagnosed asthma. This was obtained with the question “Has a doctor or nurse *ever* said that (child’s name) has asthma?” Other asthma symptom questions included questions about wheeze, persistent cough, night cough, and response to change in air temperature.

2.2.2. Anthropometric Assessment. Interviewers were trained and certified to measure weight, standing height, and body composition. Children wore a light gown and no shoes when measurements were obtained. Participants had a single tetrapolar bioimpedance measurement of resistance and reactance taken between the right wrist and ankle while in a supine position using the Quantum II RJL bioelectrical impedance analyzer (RJL, Clinton Twp, MI, USA). Interviewers were tested for intra- and interreliability. Waist circumference measurements were taken using the protocol from the National Health and Nutrition Examination Survey (NHANES) [22]. During a single interview, measurements were repeated up to three times, with results averaged for analyses. After the first two measurements were taken, the absolute difference between the two was calculated. If this difference was less than the specified tolerance level per the NHANES protocol, no further measurements were required. Otherwise, a third measurement was obtained.

2.2.3. Body Composition Calculations. The SAS program from the U.S. Centers for Disease Control and Prevention (CDC) was used to calculate body mass index percentiles based on the 2000 CDC growth charts for children 0 to 20 years of age [23]. The fat free mass (FFM) prediction equation [24] used resistance data from the RJL bioelectrical impedance analyzer to derive estimates for FFM. Estimates for total body fat (TBF) and percent body fat (% BF) for each participant were derived from their corresponding estimated FFM using the equations $TBF = \text{weight} - \text{FFM}$ and $\% BF = TBF/\text{weight}$.

2.2.4. Covariates. Pedometers were utilized as activity monitors to provide measures of movement. The mean number of pedometer steps per day was calculated for children with at least four days of steps recorded. Participation in various activities was reported (hours per week and months per year). Metabolic equivalent (MET) values assigned to each type of activity [25] were then used to convert to MET-hours per week of moderate to vigorous activity averaged over the year. Time spent each day in sedentary activities was

also reported in the questionnaire. Other questionnaire data included age, birth weight, breast feeding history, exposure to environmental tobacco smoke, and socioeconomic status. Race/ethnicity was derived using information given about national origin of each child's parents and grandparents. Children whose parents or grandparents were born in a Spanish-speaking country other than Mexico, the Dominican Republic, or Puerto Rico, or who were not born in the same country were categorized as "other/mixed Hispanic."

2.2.5. Statistical Analyses. Analyses were performed using SPSS, version 16.0 software (SPSS Inc, Chicago, Ill) and SAS version 9.1.3 (SAS, Inc., Cary, NC 27513). Descriptive statistics for all variables were examined for the whole group and among asthmatics and nonasthmatics. Differences between asthmatics and nonasthmatics were examined using chi-square tests. Body measures were compared for children from different racial ethnic subgroups by comparing means using ANOVA testing. BMI percentiles, percent body fat, waist circumference, and waist-to-height ratio were ranked into sex-specific quintiles. The top quintile and combined middle two quintiles (Q 3-4) of sex-specific body fat measure were compared to the combined bottom two quintiles (Q 1-2). The main dependent variable was the binary variable of whether the subject had parental report of physician diagnosed asthma. Poisson regression was performed using Proc Genmod to estimate adjusted prevalence ratios (PR) and 95% confidence limits (CI) rather than odds ratios because of the cross-sectional nature of the data. Models all included sex-specific quintiles of the body fat measurements, age in months, gender, and ethnicity. Other potential covariates for multivariable models were chosen prior to the study based on known or suspected relationships with body fat measures and asthma. These additional variables were entered into the models to check for evidence of confounding (change in PR estimates by more than 10%).

3. Results

Overall, about 80% of the participants ($n = 505$) were female, and there were fairly equal numbers of children at ages 6, 7, and 8 years (see Table 1). In terms of race/ethnicity, 26.5% of children were described as non-Hispanic Black, and the remainder were classified as one of the Hispanic subgroups or as other/mixed Hispanic. Most families lived in East Harlem, New York, had government health insurance and had a household income of less than \$50,000 per year (with 54% reporting incomes below \$25,000 per year). There was parental report of physician diagnosed asthma in about 26% of children and similar prevalence of asthma symptoms. More than two thirds of the children had ever been breastfed, and more than one third of families had at least one smoker in the home.

In bivariate associations between participant characteristics and asthma diagnosis (see Table 2), there was no significant association with gender or age. Asthma rates were higher in Puerto Rican, other/mixed Hispanic, and non-Hispanic Black children than in Mexican children ($P < .001$).

TABLE 1: Descriptive characteristics New York City children 2004–2007.

Characteristic	Total <i>N</i>	<i>N</i> (%)
Doctor-diagnosed asthma	505	131 (25.9%)
Ever wheeze	505	142 (28.1%)
Persistent cough	505	111 (22.0%)
Night time cough	505	153 (30.3%)
Breathing problem with temp change	505	120 (23.8%)
Gender		
Female	505	400 (79.2%)
Male		105 (20.8%)
Age		
6 years		193 (38.4%)
7 years	503	159 (31.6%)
8 years		151 (30.0%)
Ethnicity		
Mexican		143 (28.3%)
Dominican		41 (8.1%)
Puerto Rican	505	101 (20.0%)
Other/Mixed/Unknown Hisp		86 (17.0%)
Non-Hisp Black		134 (26.5%)
Income		
<\$12,000		83 (18.2%)
\$12,000–\$24,999	457	166 (36.3%)
\$25,000–\$49,999		147 (32.2%)
≥\$50,000		61 (13.3%)
Neonatal ICU		
Yes	499	86 (17.2%)
No		413 (82.8%)
Ever breastfed		
Yes	502	351 (69.9%)
No		151 (30.1%)
Smokers at home		
0		328 (65.0%)
1	505	125 (24.8%)
2+		52 (10.3%)

There were no associations between socioeconomic factors and asthma diagnosis. These factors included residence in East Harlem, household income, number of people per room in the home, and type of insurance (only data for income shown). Birth weight and history of stay in the neonatal intensive care unit were not significantly different between asthmatics and nonasthmatics. Asthma rates were higher in children who had never breastfed (35.1%) compared to children who had ever breastfed (21.9%) ($P = .008$). Asthma rates were also proportionately higher in homes with more smokers ($P = .006$).

Overall, for the 105 boys with measurements, 15.2% were overweight (BMI between 85th and 95th percentile) and 38.1% were obese (BMI greater than 95th percentile).

TABLE 2: Asthma rates for subgroups of New York City children 2004–2007.

Characteristic	Asthmatics	Nonasthmatics	<i>P</i> value*
Gender			
Female	101 (25.3%)	299 (74.7%)	.490
Male	30 (28.6%)	75 (71.4%)	
Age			
6 years	54 (28.0%)	139 (72.0%)	.373
7 years	44 (27.7%)	115 (72.3%)	
8 years	33 (21.9%)	118 (78.1%)	
Ethnicity			
Mexican	19 (13.3%)	124 (86.7%)	<.001
Dominican	7 (17.1%)	34 (82.9%)	
Puerto Rican	41 (40.6%)	60 (59.4%)	
Other/Mixed Hisp	28 (32.6%)	58 (67.4%)	
Non-Hisp Black	36 (26.9%)	98 (73.1%)	
Income			
<\$12,000	22 (26.5%)	61 (73.5%)	.183
\$12,000–\$24,999	41 (24.7%)	125 (75.3%)	
\$25,000–\$49,999	31 (21.1%)	116 (78.9%)	
≥\$50,000	22 (36.1%)	39 (63.9%)	
Neonatal ICU			
Yes	29 (33.7%)	57 (66.3%)	.212
No	99 (24.0%)	314 (76.0%)	
Ever breastfed			
Yes	77 (21.9%)	274 (78.1%)	.008
No	53 (35.1%)	98 (64.9%)	
Smokers at home			
0	73 (22.3%)	255 (77.7%)	.006
1	36 (28.8%)	89 (71.2%)	
2+	22 (42.3%)	30 (57.7%)	

* chi square test of proportions comparing asthma rates across groups.

In comparison, for the 398 girls with measurements, 15.6% were overweight and 23.4% were obese. Mean BMI percentile was higher in boys than girls (75.0 versus 65.9, $P = .006$). Similarly, boys had higher mean waist circumference (64.3 cm versus 62.4 cm, $P = .074$) and waist-to-height ratio (0.51 versus 0.50, $P = .04$). However, girls had higher mean percent body fat (20.5% versus 18.4%, $P = .08$). Hispanic children had higher BMI and body fat percent and more centrally located body fat compared to non-Hispanic-Black children (see Table 3).

Children with BMI percentile in the highest quintile of our sample were obese with an age- and gender-specific BMI percentile above the 96th percentile in girls and 98th percentile in boys (see Table 4). It is commonly accepted that a BMI value above the 95th percentile based on CDC growth curves is defined as obese. There are very limited published data about body fat norms in children (especially ethnic minority children). However, body fat percentage of 30% has been used as a cutoff to describe elevated body fat levels

[26]. Percent body fat by bioimpedance analysis revealed that the top quintile of our sample had a percent body fat above 29.1% in boys and 30.4% in girls. Waist circumference above the 90th percentile was used to define abdominal obesity in the recent National Health and Nutrition Examination Survey (NHANES) [27]. In this large, nationally representative sample of children, 71 cm was the 90th percentile for waist circumference for all 8 year old boys and girls. The top quintile of our sample including even younger children had a waist circumference above 74.6 cm in boys and 71.2 cm in girls. A waist-to-height ratio of 0.5–0.55 has also been used to define abdominal obesity regardless of age and gender [28]. The top quintile in our sample had a waist-to-height ratio above 0.58 in boys and 0.56 in girls. Thus, overall the highest quintile in our sample includes obese children by each adiposity measure based on available definitions of obesity.

Table 5 shows prevalence ratios comparing the highest quintile of each body fat measure to the combined lowest two quintiles. Higher BMI percentile, percent body fat, and waist circumference all were associated with a higher likelihood of physician diagnosed asthma in models adjusted for age, race/ethnicity and gender. Estimates for the highest quintile of waist-to-height ratio compared to the combined lowest two quintiles were similar but not statistically significant. The addition of other variables did not alter PR estimates by more than ten percent. These variables included residence in East Harlem, language spoken at home, household income, type of health insurance, number of people per room at home, birth weight, history of stay in the NICU, whether the child ever breastfed, and number of smokers at home. In terms of physical activity, models including mean number of daily pedometer steps, metabolic hours per week from recreational activity, and total sedentary hours did not significantly alter the relationship between body fat and asthma diagnosis. Thus, only models adjusting for age, race/ethnicity, and gender are presented. Interactions were also considered between gender, ethnicity, physical activity levels, and body measures. None of the interactions was significant.

Table 6 shows selected predictor variables for an explanatory asthma model. Variables in the model were chosen based on known or suspected relationships with asthma. Similar results were seen when using other body fat measures (data not shown). Age, gender, and socioeconomic status (as measured by number of people per room in child's home) were not significantly associated with reported asthma diagnosis. Puerto Rican children had significantly higher rates of asthma diagnosis compared to the referent group of Mexican children in all models. Children in the highest sex-specific BMI percentile were more likely to have a diagnosis of asthma than children in the combined lowest two quintiles. Children with more MET-hours of recreational activity also had less diagnosed asthma. Mean number of pedometer steps and number of sedentary hours were not initially included in the models due to missing data. Analyses were performed on subsets of children with data available for each of these variables and neither was significantly associated with asthma (data not shown).

TABLE 3: Body fat measures by ethnicity in boys and girls aged 6-to-8 years.

Body fat measurement	Race/ethnicity (N)	Mean (SD)	P value
Body mass index (BMI) (kg/m ²)	Mexican (143)	18.0 (3.3)	.001*
	Dominican (41)	19.4 (5.0)	
	Puerto Rican (100)	19.0 (3.2)	
	Other/Mixed Hispanic (68)	18.5 (3.2)	
	Non-Hispanic Black (133)	17.2 (3.5)	
	Total (485)	18.2 (3.7)	
Percentile for BMI for age	Mexican (143)	70.1 (28.0)	<.001*
	Dominican (41)	72.1 (33.7)	
	Puerto Rican (100)	74.2 (27.7)	
	Other/Mixed Hispanic (68)	74.9 (26.5)	
	Non-Hispanic Black (133)	58.3 (32.1)	
	Total (485)	68.6 (30.0)	
Waist circumference (cm)	Mexican (143)	63.4 (8.6)	<.001*
	Dominican (41)	65.2 (10.2)	
	Puerto Rican (100)	65.2 (10.7)	
	Other/Mixed Hispanic (68)	64.4 (8.5)	
	Non-Hispanic Black (133)	59.7 (9.1)	
	Total (485)	63.0 (9.5)	
Waist circumference/height	Mexican (143)	0.52 (0.06)	<.001*
	Dominican (41)	0.51 (0.07)	
	Puerto Rican (100)	0.52 (0.07)	
	Other/Mixed Hispanic (68)	0.51 (0.06)	
	Non-Hispanic Black (133)	0.47 (0.06)	
	Total (485)	0.50 (0.06)	
Percent body fat	Mexican (143)	21.6 (8.9)	<.001*
	Dominican (41)	23.3 (11.5)	
	Puerto Rican (100)	22.2 (10.8)	
	Other/Mixed Hispanic (68)	21.9 (9.3)	
	Non-Hispanic Black (133)	15.9 (13)	
	Total (485)	20.3 (11.2)	

* Differences between groups by ANOVA test in unadjusted models.

4. Discussion

In this study, higher body mass index percentile, percent body fat, and waist circumference all were associated with more physician diagnosed asthma. It is likely that no one factor fully explains the relationship between obesity and asthma. Clarifying which measures of adiposity are associated with asthma may help us understand some of the potential mechanisms linking these two conditions. A positive association between percent body fat and asthma implies that adipose tissue directly affects the airways. Inflammatory mediators produced by adipose tissue may cause airway inflammation [11]. In addition, the association of central body fat distribution (higher waist circumference and waist-to-height ratio) and asthma diagnosis suggests that there are mechanical effects such as reduction of lung tidal volume and functional residual capacity. Further work involving simultaneous measurement of body fat, inflammatory markers, and pulmonary function testing is needed to better understand these pathways.

Body fat levels for an “obese” BMI and fat distribution vary significantly based on race/ethnicity. The use of different adiposity measures helps address this. Only a handful of studies to date have specifically targeted ethnic minority children [29–31], and no studies have been done taking into account specific Hispanic subgroups. We found that Puerto Rican, mixed Hispanic, and non-Hispanic Black children had higher rates of asthma diagnosis than Mexican children after adjusting for body fat measurements. Other studies have also found that asthma is more prevalent in African American and Hispanic children [32] and that among Hispanics, Puerto Rican children have especially high risk, with prevalence rates as high as 35% among Puerto Rican children living in East Harlem [33, 34]. The reasons for higher asthma rates in these groups are currently unclear, and more work must be done to clarify if the increased risk is genetic, environmental or a combination of the two. Although certain ethnic minority subgroups seem to be clearly at increased risk for asthma, adiposity measures were

TABLE 4: Body fat measure quintile cutpoints in black and Hispanic boys and girls aged 6-to-8 years.

	Boys (<i>n</i> = 105)			Girls (<i>n</i> = 400)		
	Quintile (N)	Min–Max	Quintile (N)	Min–Max		
Body mass index percentile (CDC age/gender specific)	1 (21)	2.1–52.1%ile	1 (81)	<1–34.1%ile		
	2 (21)	52.2–71.2%ile	2 (80)	34.2–65.2%ile		
	3 (21)	71.3–94.1%ile	3 (80)	65.3–83.5%ile		
	4 (21)	94.2–98.5%ile	4 (80)	83.6–96.2%ile		
	5 (21)	98.6–99.9%ile	5 (79)	96.3–99.9%ile		
Body fat percent	1 (21)	<7.3%	1 (84)	<11.8%		
	2 (21)	7.3–14.8%	2 (79)	11.8–16.9%		
	3 (21)	14.9–21.6%	3 (79)	17.0–21.9%		
	4 (21)	21.7–29.0%	4 (79)	22.0–30.3%		
	5 (21)	29.1–39.4%	5 (79)	30.4–58.0%		
Waist circumference (cm)	1 (21)	47.5–55.9 cm	1 (79)	46.5–54.2 cm		
	2 (21)	56.0–59.1 cm	2 (79)	54.3–57.4 cm		
	3 (21)	59.2–65.0 cm	3 (82)	57.5–62.9 cm		
	4 (21)	65.1–74.5 cm	4 (80)	63.0–71.1 cm		
	5 (21)	74.6–87.8 cm	5 (80)	71.2–100.5 cm		
Waist/height ratio	1 (21)	0.39–0.44	1 (80)	0.39–0.43		
	2 (21)	0.45–0.47	2 (80)	0.44–0.46		
	3 (21)	0.48–0.51	3 (80)	0.47–0.50		
	4 (21)	0.52–0.57	4 (81)	0.51–0.55		
	5 (21)	0.58–0.69	5 (79)	0.56–0.72		

TABLE 5: Adjusted prevalence ratios for quintiles (Q 1–Q 5) of four body fat measures in relation to physician-diagnosed asthma.

	Asthma versus no asthma PR (95% CI)
BMI percentile	
Q 3+4 versus Q 1+2	1.24 (0.86–1.79)
Q 5 versus Q 1+2	1.63 (1.12–2.39)**
Percent body fat	
Q 3+4 versus Q 1+2	1.16 (0.81–1.67)
Q 5 versus Q 1+2	1.50 (1.02–2.21)**
Waist circumference	
Q 3+4 versus Q 1+2	1.31 (0.91–1.88)
Q 5 versus Q 1+2	1.56 (1.04–2.34)**
Waist-to-height ratio	
Q 3+4 versus Q 1+2	1.14 (0.79–1.64)
Q 5 versus Q 1+2	1.31 (0.86–2.00)

Each model adjusted for age in months, race/ethnicity and gender.

***P* < .05.

associated with asthma even after inclusion of ethnicity in the models.

The question of gender differences in the asthma-obesity association in children remains unanswered and studies to date have had mixed results [5]. Although sex-specific fat measures were used, it was not possible to stratify by gender because there were so many more girls than boys in this study.

One limitation in previous studies has been the failure to adjust for physical activity levels. One study [35] adjusted

TABLE 6: Explanatory asthma model.

<i>N</i> = 434	Asthma versus no asthma PR (95% CI)
BMI percentile	
Q 3-4 versus Q 1-2	1.18 (0.80–1.73)
Q 5 versus Q 1-2	1.58 (1.05–2.37)*
Race/ethnicity (referent = Mexican)	
Dominican	0.68 (0.28–1.68)
Puerto Rican	2.32 (1.08–4.99)*
Other/mixed Hispanic	2.02 (0.92–4.46)
Non-Hispanic black	1.91 (0.91–4.02)
Age in years	0.97 (0.80–1.18)
Gender (referent = male)	1.02 (0.70–1.50)
#People/#rooms at Home	1.17 (0.76–1.80)
Ever breastfed (referent = yes)	1.24 (0.87–1.76)
#Smokers at home	1.11 (0.95–1.30)
Metabolic hours of recreational Activity	0.98 (0.96–1.00)*

**P* < .05.

BMI for participation in sports and number of hours per week in sports practice. Another cross-sectional study looked at the association of obesity and current wheezing and adjusted for physical activity level by questionnaire [36]. Physical activity is notoriously difficult to measure accurately. Devices such as pedometers more objectively measure activity levels by capturing number of steps taken

per day. Although we had both questionnaire-based and objective physical activity measures on our study population, inclusion of these physical activity variables in the models did not significantly alter the relationship between body fat measurements and asthma.

Change in lifestyle may explain the co-occurrence of obesity and asthma [4, 5]. For example, obesity is associated with decreased physical activity levels and a high-calorie diet, and these behaviors rather than obesity may be related to the development of asthma. One important limitation of this study is that it was cross-sectional. Children with low levels of physical activity who become obese may be at increased risk for development of asthma or asthmatic children may limit their activity and become obese. Both of these scenarios may contribute to the relationship between obesity and asthma. A few longitudinal studies provide evidence that low levels of physical activity are associated with future development of asthma [37, 38]. Our study found that children with more MET-hours of recreational activity had less diagnosed asthma. Longitudinal studies have also shown that higher body mass index is associated with future asthma [4, 5]. We will also have the opportunity to study the relationship between different body fat measures, physical activity levels, and asthma diagnosis over time. Data from detailed dietary assessments will also be available in the future to better understand the interplay between health related behaviors, obesity and asthma.

One potential limitation is that we used parental report of physician-diagnosed asthma as our main asthma outcome. Other possible asthma outcomes include report of symptoms, pulmonary function testing, and methacholine challenge testing. However, report of physician-diagnosed asthma has been used widely as a measure of asthma diagnosis in large epidemiologic studies such as NHANES [39]. Furthermore, rates of asthma in our study are consistent with other local estimates of asthma prevalence using more detailed measures for asthma diagnosis [33, 40].

5. Conclusion

This study found that higher body mass index percentile, percent body fat, and waist circumference were associated with reported physician diagnosed asthma. Recent reviews of asthma and obesity in children have noted problems with the definition of obesity because of the known limitations of BMI in assessing adiposity. Here, we verified the relationship between obesity and asthma using measurement of body fat percentage and not just the proxy measure of BMI. We were also able to examine the relationship between fat distribution and asthma diagnosis.

The association between different body fat measures and asthma in children has important clinical and public health significance. Pediatricians should be aware of the relationship between obesity and asthma and counsel families with overweight children about this association, especially if there are already other asthma risk factors such as ethnicity or positive family history. Asthma is a disease which has immediate and significant impact on a child's daily life.

Counseling families about the association between obesity and asthma may be a powerful motivator for weight control.

Percent body fat and waist circumference are better than BMI in describing body composition. This also could have important health implications. For example, waist circumference has been shown to predict cardiovascular risk better than BMI [28]. As more studies are done examining relationships between alternate body fat measures and disease, there may be a need for pediatricians to use these alternative measures in overweight children to more accurately estimate health risk.

Disclosure

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