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Childhood Obesity and Asthma Control in the GALA II and SAGE II Studies

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***Rationale*: Obesity is associated with increased asthma morbidity, lower drug responsiveness to inhaled corticosteroids, and worse asthma control. However, most prior investigations on obesity and asthma control have not focused on pediatric populations, considered environmental exposures, or included minority children.**

***Objectives*: To examine the association between body mass index categories and asthma control among boys and girls; and whether these associations are modified by age and race/ethnicity.**

***Methods*: Children and adolescents ages 8–19 years (n = 2,174) with asthma were recruited from the Genes-environments and Admixture in Latino Americans (GALA II) Study and the Study of African Americans, Asthma, Genes, and Environments (SAGE II). Ordinal logistic regression was used to estimate odds ratios (OR) and their confidence intervals (95% CI) for worse asthma control.**

***Measurements and Main Results*: In adjusted analyses, boys who were obese had a 33% greater chance of having worse asthma control than their normal-weight counterparts (OR, 1.33; 95% CI, 1.04–1.71). However, for girls this association varied with race and ethnicity (*P* interaction = 0.008). When compared with their normal-weight counterparts, obese African American girls (OR, 0.65; 95% CI, 0.41–1.05) were more likely to have better controlled asthma, whereas Mexican American girls had a 1.91 (95% CI, 1.12–3.28) greater odds of worse asthma control.**

***Conclusions*: Worse asthma control is uniformly associated with increased body mass index in boys. Among girls, the direction of this association varied with race/ethnicity.**

AT A GLANCE COMMENTARY

Scientific Knowledge on the Subject

Obesity and asthma are common health conditions among US children. Obesity is associated with asthma control, although the mechanism is not well-understood.

What This Study Adds to the Field

Worse asthma control is uniformly associated with increased body mass index in boys. Boys who were obese had increased odds of having worse asthma control than their normal-weight counterparts after adjusting for selected characteristics. For girls, this association depended on race and ethnicity. Thus, asthma control programs should account for body mass index and demographic characteristics of children.

Keywords: obesity; asthma control; race and ethnicity; age; sex

Obesity and asthma are among the most challenging health conditions affecting children and adolescents in the United States. Among this segment of the population, obesity (1) and asthma (2) prevalence vary by sex. For example, obesity is more common among boys (18.6%) than among girls (15%) aged 2–19 years old (1). This is also true for asthma with boys (10.5%) being more likely to have asthma than girls (8.2%) (2). Given these sex differences, obesity and asthma should be examined among boys and girls separately.

Further variations on obesity and asthma are observed across age and race/ethnicity (1, 2). It is estimated that 32.6% of US children ages 6–11 years and 33.6% of adolescents ages 12–19 are overweight or obese (1). The prevalence of obesity is significantly higher among Mexican (23.9%) and African American (23.7%) children compared with non-Hispanic whites (16.1%) (1). Moreover, there are sex-specific differences in

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obesity prevalence across racial-ethnic groups, with Mexican (28.9% and 18.6%) and African American (22.6% and 24.8%) boys and girls having higher prevalence than their non-Hispanic white counterparts (16.1% and 14%) (1). Likewise, there are significant differences in asthma prevalence and morbidity among US children (3). It is estimated that 9.3% of children ages 5–10 and 10% of adolescents ages 11–17 have asthma (4). Moreover, the prevalence of asthma varies across racial-ethnic groups with higher prevalence among African Americans (15.9%) and Puerto Ricans (19.5%) but lower prevalence among Mexican Americans (6.9%) compared with non-Hispanic whites (8.2%) (2). Thus, it is possible that the association between obesity and asthma among boys and girls varies with age and race/ethnicity.

Most epidemiologic studies have consistently shown an association between obesity and asthma (5–8). In addition, obesity is associated with lower drug responsiveness to inhaled corticosteroids (9) and worse asthma control (10–16). Although the mechanism is not well understood, it is possible that obesity may be associated with worse asthma control by the immunomodulatory effects of adipokines and alterations in the cytokine milieu (17, 18). Moreover, the effects of adipokines and cytokines may vary with sex and race/ethnicity (19, 20). For instance, in one study comprised mostly of inner-city African American and Hispanic adolescents, Kattan and colleagues (13) demonstrated that increased adiposity was associated with poorer asthma control among girls but not boys. However, most prior investigations examining obesity and asthma control have not focused on pediatric populations, considered environmental exposures, or included minority children (21–24).

Developing a better understanding of the relationship between obesity and asthma control among racially and ethnically diverse pediatric populations may have important public health implications, including the development of tailored clinical and public health interventions. In a large population of African American and Hispanic children and adolescents with asthma, we examined the association between body mass index (BMI) categories and asthma control among boys and girls, and whether these associations are modified by age and race/ethnicity.

METHODS

The Genes-environments and Admixture in Latino Americans (GALA II) Study and the Study of African Americans, Asthma, Genes, and Environments (SAGE II) are ongoing clinic-based multicenter asthma case-control studies, organized from the coordinating center based at the University of California, San Francisco, and conducted using identical protocols and questionnaires, to examine the complex genetic and environmental contributors to asthma prevalence, control, and severity among minority children and adolescents (*see* Tables E1 and E2 in the online supplement) (25). Each participating center's Institutional Review Board reviewed and approved the study. Written informed consent was provided by each child's parent or legal guardian and if 18 and older, by the subject. For this cross-sectional analysis, the study sample includes data from the baseline examination of children with asthma recruited in GALA II (n = 2,022) and SAGE II (n = 769) through November 2011.

Exposure

BMI at time of recruitment was calculated using weight and height measures for each participant. Because BMI varies across age and sex among children (26, 27), standardized sex- and age-specific growth charts were used to calculate BMI percentiles (http://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm). For this analysis, children were classified as follows: normal (5th to <85th percentile); overweight (≥85th to <95th percentile); and obese (≥95th percentile) (28).

Outcome

Asthma control information was collected through a modified version of the 1978 American Thoracic Society–Division of Lung Diseases Epidemiology Questionnaire (29) on symptoms, nighttime awakening, interferences with normal activities, rescue medication use, and lung function measurements (*see* Table E3). Consistent with a previous study (25), asthma control was defined using a modification of the NHLBI guidelines to fit our questionnaire as controlled, partially controlled, or poorly controlled (*see* Table E3) (30).

Covariates

Consistent with previous studies (13, 25, 31), age, sex, race/ethnicity, secondhand smoke exposure, asthma medication use, and season of recruitment (February to May, June to August, September to November, December to January) were considered as potential confounders and included in the analysis. Age was recorded as a continuous variable and further categorized as less than 12 or 12 or more years as a general marker for puberty (32). Self-reported race/ethnicity was collected using two separate questions in serial (*see* Table E4). Ethnicity was collected through the question "Did you consider yourself Spanish/Hispanic/Latino?" with a "Yes/No" choice (if yes, please specify: Mexican, Mexican American, Chicano; Spanish, Hispanic, Latino; Dominican; Cuban, and so forth). Race was collected through the question "What is your race? Would you say…White; Black, African American, or Negro; American Indian or Alaska Native; Asian Indian; Chinese; Filipino; Japanese; Korean; Vietnamese; Other Asian; Native American; Native Hawaiian; Guamanian or Chamorro; Samoan; Other Pacific Islander; or Other (please specify). Multiple selections were allowed for each question. The subject (or the subject's parents) selected the appropriate answers to all questions for the subject, parents, and grandparents, and responses were used to categorize subjects as African American, Mexican American, mainland Puerto Rican, and island Puerto Rican or mixed or other ethnicity. Mainland and Island Puerto Ricans were treated as separate categories to account for environmental and cultural differences.

Secondhand smoke exposure was assessed by the reported number of household smokers currently living with the subject (none, one, or two or more). Subjects' asthma prescriptions were grouped into five different treatment categories: (*1*) no medications, (*2*) rescue inhalers or short-acting β agonists only, (*3*) controller monotherapy, (*4*) combination therapy, and (*5*) oral corticosteroids (OCS). Total plasma IgE was measured in duplicate for all subjects on the ImmunoCAP 100 system (Phadia, Kalamazoo, MI) and dichotomized at a cut-off of greater than or equal to 100 IU/ml to indicate an elevated total IgE level (33).

Of the 2,791 GALA II and SAGE II study participants with asthma, 617 subjects were excluded because they were age 20 years and over (n = 94) given that the use of BMI percentile is recommended up to age 20; had missing BMI information (n = 19); BMI less than fifth percentile (n = 88); extremely high BMIs (BMI >60; n = 3); were mixed or non-Mexican/non-Puerto Rican Hispanic ancestries to remove nonhomogenous groups and reduce confounding (n = 363); and had missing information on secondhand smoke exposure (n = 50). These exclusion criteria yielded an analytical sample of 2,174.

Statistical Analysis

Because of sex differences in obesity and asthma (1, 2), descriptive statistics were calculated according to sex and for the overall population. Baseline differences between boys and girls were determined using *t* test and chi-square statistics. After assessing and meeting the proportional assumption in boys ($P = 0.49$) and girls ($P = 0.47$), ordinal logistic regression was used to estimate the strength of the association between BMI categories (overweight and obese relative to normal) and asthma control among boys and girls before and after adjusting for selected characteristics. The ordinal model assumes parallel regression lines for the three categories of asthma control. For example, the three categories of control are modeled as two parallel lines with grouped binary outcomes. Line 1 assumes a comparison between well-controlled asthma versus partially controlled and poorly controlled asthma, whereas line 2 contrasts well-controlled and partially

controlled asthma with poorly controlled asthma. Because the two lines have the same parameter estimates (slopes), there is only one odds ratio (OR) for each predictor variable in the model (34). To determine whether the association between BMI categories and asthma control was modified by age or race/ethnicity, interaction terms were tested between BMI and age categories and also between BMI categories and race/ethnicity in the adjusted model for boys and girls. A P value of 0.05 was used to assess the significance of main effect associations, whereas a P value of 0.10 was used to determine interactions. All analyses were conducted with R 2.13.1 (35).

RESULTS

Table 1 presents the distribution of selected characteristics according to sex and for the overall study sample. The mean age of the study population was 13 years and most participants were African American (32.2%), Island Puerto Rican (31.6%), or Mexican (28.5%). Over one-third of the sample was obese (35.6%), and almost a one-quarter reported living in households with smokers. Nearly 90% of participants reported taking prescription asthma medications and most had insufficient asthma control: 33.5% met criteria for poorly controlled asthma and 48.9% met criteria for partially controlled asthma. When compared with boys, girls were older; were less likely to have an elevated level of total plasma IgE (≥100 IU/ml); and were less likely to have decreased lung function ($P < 0.001$). It is worth noting that there was little variation in socioeconomic status in this sample as indicated by the educational attainment with 72% of mothers and 65% of fathers having a high school or General Equivalency Degree education (data not shown).

Table 2 shows the associations between BMI category and asthma control for girls and boys. For girls, there was no significant association between BMI and worse asthma control before or after adjusting for age, race/ethnicity, current smokers in the household, asthma medication regimen, and recruitment season. In contrast, boys who were obese had at least a 30% greater odds of having worse asthma control than their normal-weight

TABLE 1. SELECTED CHARACTERISTICS* OF CHILDREN AND ADOLESCENTS WITH ASTHMA SELECTED FOR THIS ANALYSIS (FROM GALA II AND SAGE II): 2008–2011

	Girls	Boys	*P* Value	Total
Total	974 (100)	1,200 (100)		2,174 (100)
Age, yr	13.2 (3.3)	12.4 (3.0)	<0.001	12.8 (3.2)
<12	421 (43)	608 (51)		1,029 (47)
≥12	553 (57)	592 (49)		1,145 (53)
Race/ethnicity			0.32	
Mexican	261 (26.8)	359 (29.9)		620 (28.5)
Mainland Puerto Rican	81 (8.3)	85 (7.1)		166 (7.6)
Island Puerto Rican	308 (31.6)	380 (31.7)		688 (31.6)
African American	324 (33.3)	376 (31.3)		700 (32.2)
BMI				
Average BMI percentile	76.4 (25.3)	76.1 (26.3)	0.80	76.2 (25.0.8)
BMI category			0.38	
Normal	465 (47.7)	545 (45.4)		1,010 (46.5)
Overweight	178 (18.3)	213 (17.8)		391 (18)
Obese	331 (34)	442 (36.8)		773 (35.6)
Current smokers in the household			0.92	
No smokers	745 (76.5)	909 (75.8)		1,654 (76.1)
One smoker	170 (17.5)	217 (18.1)		387 (17.8)
Two or more smokers	59 (6.1)	74 (6.2)		133 (6.1)
Season of recruitment			0.24	
February to May	318 (32.6)	439 (36.6)		757 (34.8)
June to August	258 (26.5)	313 (26.1)		571 (26.3)
September to November	239 (24.5)	273 (22.8)		512 (23.6)
December to January	159 (16.3)	175 (14.6)		334 (15.4)
Elevated total plasma IgE (≥100 IU/ml)	587 (60.3)	843 (70.2)	<0.001	1,430 (65.8)
Prescribed medications in the past 12 mo			0.06	
No asthma medication	113 (11.6)	107 (8.9)		220 (10.1)
Only rescue inhalers/SABA	217 (22.3)	236 (19.7)		453 (20.8)
ICS/LTRA/theophylline monotherapy	243 (24.9)	302 (25.2)		545 (25.1)
Combo therapy and/or LABA	127 (13)	169 (14.1)		296 (13.6)
Oral corticosteroids	274 (28.1)	386 (32.2)		660 (30.4)
Asthma symptoms and exacerbations				
Wheeze or shortness of breath in past week	371 (38.1)	412 (34.3)	0.07	783 (36)
Activities limited by asthma in past week	319 (32.8)	383 (31.9)	0.73	702 (32.3)
Awakened by asthma in past week	318 (32.6)	380 (31.7)	0.66	698 (32.1)
Use of rescue medication >2 in past week	284 (29.2)	402 (33.5)	0.14	686 (31.6)
Lung function				
FEV_1 <80% predicted	251 (25.8)	346 (28.8)	0.14	597 (27.5)
FEV_1/FVC <85%	439 (45.1)	704 (58.7)	<0.001	1,143 (52.6)
FEV_1 <80% or FEV_1/FVC <85%	545 (56)	782 (65.2)	<0.001	1327 (61)
Asthma control			0.07	
Well controlled	191 (19.6)	192 (16)		383 (17.6)
Partially controlled	458 (47)	605 (50.4)		1,063 (48.9)
Poorly controlled	325 (33.4)	403 (33.6)		728 (33.5)

Definition of abbreviations: BMI = body mass index; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; GALA = Genes-environments and Admixture in Latino Americans Study; ICS = inhaled corticosteroids; LABA = long-acting β agonist; LTRA = leukotriene receptor antagonist; SABA = short-acting β agonists; SAGE = Study of African Americans, Asthma, Genes, and Environments.

*All values reported as number (%) except for year age and BMI percentile values, which are reported as mean (SD).

TABLE 2. ODDS RATIOS BETWEEN POORLY CONTROLLED ASTHMA AND BMI CATEGORY BY SEX

Sex	Normal Weight	Overweight	Obese
Girls	n = 465	n = 178	n = 331
Crude	1.00	0.81 (0.58–1.12)	0.96 (0.74–1.25)
Adjusted*	1.00	0.92 (0.66–1.28)	1.01 (0.77–1.32)
Boys	n = 545	n = 213	n = 442
Crude	1.00	1.04 (0.77–1.40)	1.30 (1.02–1.65)
Adjusted*	1.00	1.05 (0.77–1.43)	1.33 (1.04–1.71)

Definition of abbreviation: BMI = body mass index.

* Odds ratio adjusted for age, race/ethnicity, current smokers in the household, prescribed asthma treatment regimen, and recruitment season.

TABLE 3. ADJUSTED* ODDS RATIOS BETWEEN POOR ASTHMA CONTROL AND BMI CATEGORY IN FEMALES ACCORDING TO AGE GROUP

Age Group	Normal Weight (*n = 465*)	Overweight (*n = 178*)	Obese (*n = 331*)	Interaction *P* Value
<12 yr	1.00	0.74 (0.44–1.25)	0.72 (0.47–1.10)	0.11
⩾12 yr	1.00	0.98 (0.62–1.53)	1.26 (0.88–1.82)	

Definition of abbreviation: BMI = body mass index.

* Odds ratio adjusted for age, race/ethnicity, current smokers in the household, prescribed asthma treatment regimen, and recruitment season.

counterparts before (OR, 1.30; 95% confidence interval [CI], 1.02–1.65) and after (OR, 1.33; 1.04–1.71) adjusting for the selected characteristics.

We examined whether the association between BMI and asthma control differs according to age categories (<12 and ⩾12 yr). Although not significant, we observed associations of opposite directions among girls according to age groups (*P* for interaction = 0.11); no heterogeneity of this association was observed among boys according to age groups (*P* for interaction = 0.998, data not shown). Obese girls younger than 12 years of age were more likely to have better-controlled asthma compared with normal-weight girls, even after adjusting for race/ethnicity, current smokers in the household, prescribed asthma treatment regimen, and recruitment season (OR for worse asthma control, 0.72; 95% CI, 0.47–1.10) (Table 3).

Finally, we examined whether the association between BMI and asthma control varies with race/ethnicity. We found no heterogeneity of the association between BMI categories and asthma according race/ethnicity for boys (*P* for interaction = 0.32). However, among girls we found that this association varied significantly with race/ethnicity (*P* for interaction = 0.008). Obese Mexican American girls had a 1.91 (95% CI, 1.12–3.28) greater odds of worse asthma control, whereas obese African American girls had a 0.65 (95% CI, 0.41–1.05) lower odds compared with their normal-weight counterparts (Table 4) after controlling for age, current smokers in the household, prescribed asthma treatment regimen, and season of recruitment. Although some of these ORs are not statistically significant, the observed opposite association between BMI and asthma control together with the significant race/ethnicity and BMI interaction, suggests that race/ethnicity may have a differential effect on this association.

DISCUSSION

Our findings suggest that obese boys are more likely than normal-weight boys to have worse asthma control. This association remained significant after adjusting for age, race/ethnicity, current household secondhand smoke exposure, prescribed asthma treatment regimen, and season. However, among girls, the association between BMI and asthma control seemed to vary with race/ethnicity: obese Mexican American girls had greater odds of worse asthma control compared with their normal-weight counterparts. In contrast, obese African American girls (overweight or obese) had greater odds of having better asthma control compared with their normal-weight counterparts.

Previous studies have examined the association between obesity and asthma control (10–16); however, only one study examined sex differences. The study by Kattan and coworkers (13) examined adolescents age 12–20 years from 10 major US urban areas and found that increased adiposity was associated with reduced asthma control among girls but not boys (13). We found a similar positive association between BMI and worse asthma control among Mexican American girls. However, in contrast to Kattan and coworkers (13), we also found a positive association between BMI and asthma control among boys and a protective effect of BMI on asthma control among younger girls and African American girls. Compared with our sample, Kattan and coworkers' (13) participants were older, more likely to be male, and African American. Moreover, their sample was more geographically heterogeneous than ours, because their participants were recruited from 10 US urban areas. We used a similar, but distinct questionnaire to Kattan and coworkers (13) and included assessment of lung function, medication use, and asthma symptoms to determine control. Moreover, we assessed asthma control at one time point using a 1-week recall, whereas Kattan and coworkers (13) assessed asthma control every 2 months over a 1-year period (13). Thus, it is possible that the difference between Kattan and coworkers (13) and our findings among boys and younger girls and African American girls could be explained by differences in sample characteristics and timing of outcome measurement.

Although our findings for the interaction between age and obesity on asthma control among boys and girls were not statistically significant, the observed difference between younger and older girls may be caused by variations associated with hormonal expression. For example, adipose tissue has been described as an endocrine organ (36–38) and male and female sex steroid hormone receptors have been identified in adipose tissue (39). Moreover, our results parallel the observation that early menarche is associated with increased risk of developing asthma among girls (40, 41). However, although we do not have menarche-related variables (or other puberty measures), we examined several additional cut-points for age (i.e., 13 and 14) and the results remained nearly unchanged. Thus, it is possible that differential hormonal expression may account for these differences.

Our observation that increased BMI was associated with worse asthma control among Mexican American girls but protective among African American girls may be explained by differences in our study. Although the prevalence of obesity was similar in both African and Mexican American girls (38% vs. 37.5%), African American girls were more likely to have poorly controlled asthma than Mexican American girls (39% vs. 20%) in our sample. In addition, there were more Mexican (43%) than African American girls (34%) in the younger category (<12 yr), which may have contributed to the observed race/ethnicity heterogeneity of the association between BMI categories and asthma control in girls.

Our results have generated important areas of future investigation and highlight potential public health intervention. It may be helpful to manage obesity among boys, younger girls, and Mexican American girls with asthma more carefully—with more frequent visits and more aggressive medication regimens—to achieve better asthma control. However, it may be beneficial to help maintain a healthy BMI and implement weight management

TABLE 4. ADJUSTED* ODDS RATIOS BETWEEN POOR ASTHMA CONTROL AND BMI CATEGORY IN FEMALES ACCORDING TO RACE/ETHNICITY

Race/ethnicity	Normal Weight	Overweight	Obese	Interaction *P* Value
Mexican	1.00	1.27 (0.66–2.47)	1.91 (1.12–3.28)	0.008
Mainland Puerto Rican	1.00	0.66 (0.16–2.76)	0.87 (0.31–2.41)	
Island Puerto Rican	1.00	0.78 (0.43–1.40)	0.94 (0.56–1.56)	
African American	1.00	0.79 (0.44–1.43)	0.65 (0.41–1.05)	

Definition of abbreviation: BMI = body mass index.

*Odds ratio adjusted for age, current smokers in the household, prescribed asthma treatment regimen, and recruitment season.

treatment programs to eliminate or reduce the effect of obesity on asthma control among children and adolescents regardless of age, sex, and race/ethnicity.

The literature suggests that obesity precedes and predicts asthma (42–44). However, differences in genetics, early life experiences, and environmental exposures may affect the temporality between obesity and asthma. Although there are shared factors contributing to the occurrence of both processes, the treatments for asthma and obesity differ. The lack of immediate results from weight management, asthma medication compliance, and the cultural barriers to the treatment of both disease processes can lead to lack of asthma control. As providers work to overcome the barriers to successfully treating cooccurring asthma and obesity, it is important to focus on the aspects of treatment that are most beneficial to particular individuals.

Our study has several limitations, and our results should be interpreted in the context of these limitations. First, our study was cross-sectional, and therefore precluded us from making any temporal association between the exposure and the outcome. Second, subjects were recruited as part of a clinic-based case-control study among minority US populations. Therefore, our estimates of asthma control should not be interpreted as prevalence or extrapolated to the general US population. Third, our assessment of asthma control was limited to 1-week. This limited period may have underestimated or overestimated the true asthma control for participants, resulting in nondifferential misclassification, and thus biasing our estimates toward the null. Fourth, unlike the National Asthma Education Prevention Program (45) guidelines on asthma control, we did not consider asthma symptoms and exacerbations separately. This may have led to underestimation of our asthma control measures and our results. Additionally, we may not have controlled for all factors related to obesity and poor asthma control. Moreover, the aggregation of treatment options into five categories (no medications, rescue inhalers only, controller monotherapy, combination therapy, and oral systemic steroids) may be problematic. However, we repeated the analyses after grouping medication into different combinations (e.g., yes vs. no control medication; no medication; non-OCS medication; and OCS) and our main results and the interaction results remained nearly identical. Thus, it is very unlikely that the categories used to assess medications for asthma have affected our results. Additionally, the lack of a measure of adherence to medication or dose for antiinflammatory medication may have biased out results toward the null because of offsetting of those overreporting and those underreporting adherence to medication and/or antiinflammatory medication.

In addition, our estimates may be affected by misclassification or recall bias of secondhand smoking exposures, because we rely on self-report rather than biomarkers (e.g., cotinine). However, if misclassification or recall bias was to occur it likely would have been underreported because parents would be less likely to report smoking even when they smoke to avoid guilt for their children's conditions, and therefore it may have underestimated our results given the association between smoking and asthma (46). It is unlikely that secondhand smoking reporting would be associated with obesity. Moreover, we excluded 617 participants because they were missing covariate data, BMI, or were of mixed race/ethnicity. However, when we compared participants included with those excluded in the study, the only differences observed were in mean age (13.5 yr of age for excluded vs. 12.8 for included; $P < 0.05$). Finally, our study did not have a nonminority or white reference group, limiting the generalizability of our findings only to Hispanic-Latino and African American children and adolescents.

To our knowledge this is the first examination of obesity, age, sex, and race/ethnicity with asthma control in a large population of Hispanic-Latino and African American children and adolescents. Our results suggest that asthma control is associated with elevated BMI among boys regardless of age and race/ethnicity. However, for girls, the direction of this association is dependent on race/ethnicity. These findings may inform future studies investigating this complex, multifactorial association, such as examining social factors, hormonal contributions, and their interactions to affect disease expression.

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