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Relationship between childhood body mass index and young adult asthma

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Abstract

Background—The relationship between obesity and asthma is an area of debate.

Objective—To investigate the association of elevated body mass index (BMI) at a young age and young adult asthma.

Methods—BMI, questionnaires, and serologic tests results were analyzed in participants of a predominantly white, middle-class, population-based birth cohort from Detroit, Michigan at 6 to 8 and 18 years of age. Asthma diagnosis was based on medical record data. Allergen specific IgE was analyzed using UniCAP, with atopy defined as 1 or more allergen specific IgE levels of 0.35 kU/L or higher. Overweight was defined as a BMI in 85th percentile or higher.

Results—A total of 10.6% of overweight males at 6 to 8 years of age had current asthma at 18 to 20 years of age compared with 3.2% of males who were normal or underweight (relative risk [RR], 3.3; 95% confidence interval [CI], 1.0–11.0; $P=.048$). A total of 19.6% of females who were overweight at 6 to 8 years of age had asthma compared with 10.3% of females who were normal or underweight (RR, 1.9; 95% CI, 0.9–3.9; $P=.09$). After adjustment for atopy at 6 to 8 years of age, overweight males had an adjusted RR of 4.7 (95% CI, 1.4–16.2; $P=.01$), and overweight females had an adjusted RR of 1.7 (95% CI, 0.8–3.3; $P=.15$). Change in BMI between 6 to 8 years of age and 18 to 20 years of age was also examined. Patients with persistently elevated BMI exhibited increased risk of asthma as young adults (RR, 2.4; 95% CI, 1.2–4.7) but not with an increasing BMI (RR, 0.8; 95% CI, 0.3–2.2) or a decreasing BMI (RR, 0.8; 95% CI, 0.3–2.2).

Conclusion—Overweight males 6 to 8 years of age have increased risk of asthma as young adults. Being overweight remains a predictor of asthma after adjustment for early atopy. A similar but not statistically significant trend was also seen among overweight females. Overweight body habitus throughout childhood is a risk factor for young adult asthma.

Introduction

Asthma and obesity are both serious public health concerns that have increased in prevalence in the United States. Asthma rates have doubled, whereas childhood obesity has

tripled in the past 30 years.^{1–3} In the United States, 1 of 5 children between 6 and 11 years of age are obese, and nearly another 30% are overweight.³ Concomitantly, childhood asthma is reported to affect nearly 7 million children younger than 18 years with a prevalence of more than 9%.⁴ Given that asthma incidence rates vary considerably in the preteen and adolescent years, studying the link between asthma and obesity may help us better understand whether obesity contributes to this variability.

Although a causal link between asthma and obesity remains controversial, an increased rate of asthma in obese and overweight individuals is evident in both adult and pediatric populations.^{5–11} Some studies have shown the risk of poorly controlled asthma in obese adults to be nearly triple that of normal weight individuals with asthma.^{12, 13} Furthermore, increasing body mass index (BMI; a measure of weight in kilograms divided by the square of height in meters) is associated with incrementally higher risk of incident asthma,¹⁴ suggesting a dose-dependent relationship, a finding supported by meta-analysis.¹⁵ It has been particularly difficult to delineate a timeline related to the development of obesity and asthma, and speculation continues as to which diagnosis precedes the other, with limited prospective studies being published. In one prospective study, Beckett et al¹⁶ demonstrated that a higher BMI among adults at study enrollment was associated with a higher rate of asthma 10 years later. This finding could be interpreted as counter to the theory that asthma leads to lower physical activity and results in subsequent obesity. Furthermore, Hancox et al¹⁷ reported that the presence of asthma at 9 years of age was associated with a lower BMI at 26 years of age in both males and females (mean difference 1.47; 95% confidence interval [CI], 0.33–2.6). Several other investigators have examined the role of birthweight, current weight, and/or rate of weight gain among infants and children in determining present or future occurrence of asthma with somewhat conflicting results. For instance, a meta-analysis of 4 independent studies concluded that school-aged children with a high body weight have a future risk of asthma equal to 1.5 times the risk of children without high body weight.¹⁸ In contrast, Mamun et al¹⁹ found that elevated BMI at 5 years of age was not associated with asthma at 14 years of age. However, children with a *rising* BMI from 5 years to 14 years of age had increased asthma symptoms at 14 years of age.¹⁹ Given the limited studies available and conflicting results, further studies delineating this relationship may be informative. The goal of this study was to evaluate the relationship between BMI at 6 to 8 years of age and current asthma in 18- to 20-year-old participants in a population-based birth cohort from Detroit, Michigan.

Methods

Data were collected as part of the Childhood Allergy Study as previously described.²⁰ Briefly, we studied children of mothers recruited to participate in a Detroit area, population-based birth cohort study of early life risk factors for allergic diseases and asthma. The study enrolled women who were members of a southeast Michigan health maintenance organization and received their prenatal care from a Henry Ford Health System physician. A total of 835 predominantly middle class, white, pregnant women, 18 years and older and with an expected date of confinement between April 15, 1987, and August 31, 1989, were enrolled without regard to allergic history. Institutional review board approval was obtained before study onset. Written informed consent was obtained, and a prenatal interview was conducted. Children born at 36 weeks' gestational age or later were included in the study. Annual telephone questionnaires were performed on the anniversary of their birth date until and including the child's sixth birthday. Between the ages of 6 and 7 years, a general medical history, physical examination, including height and weight measurements, and venous blood draw were performed. Analysis for allergen specific IgE levels was performed according to the standard manufacturer's protocols with the Pharmacia UniCAP system (Phadia, Portage, Michigan) for *Dermatophagoides farinae*, peanut, dog, cat, Timothy grass,

short ragweed, and *Alternaria alternata*. Atopy was defined as having at least 1 allergen specific IgE result of 0.35 kU/L or greater. A total of 484 of the 835 initial children (58%) took part in a medical examination at a mean age of 6.7 years, and blood samples were obtained on 382 children. A total of 424 of the 484 children (88%) were contacted after their 18th birthday and participated in an interview, clinic visit, and medical examination at a mean age of 18.3 years. Ever asthma was defined by physician-diagnosed asthma on at least one occasion on review of the following sources: (1) medical record abstracting; (2) caregiver questionnaire; (3) participant interviews; and (4) review of electronic claims that indicated a diagnosis of asthma via *International Classification of Diseases, Ninth Revision* (ICD-9) coding.

Current asthma criteria required physician diagnosed asthma (as defined above) and one or more of the following: (1) self-reported asthma symptoms in the past year and/or (2) use of asthma medications (controller or rescue medications) in the past year.

BMI at 6 to 7 years of age and 18 to 20 years of age was calculated from each participant's height and weight at their study related visit. Children were classified according to the Centers for Disease Control and Prevention's established categories of underweight (<5th percentile), normal weight (5th to <85th percentile), overweight (85th to <95th percentile), and obese (≥95th percentile).²¹ For our analyses, underweight (n=8) and normal weight (n=323) indices were combined into a category of "nonelevated BMI" as were the overweight (n=62) and obese (n=31) indices to create a category of "elevated BMI."

We used χ^2 tests to compare the distribution of categorical variables, such as sex, race, or current asthma status between groups. Relative risks (RRs) are presented with 95% CIs. Generalized linear models with robust SEs were used to calculate adjusted relative risks (aRRs) with 95% CIs for associations between BMI and current asthma with adjustment for atopy.²² All analyses were performed using SAS statistical software (version 9.2; SAS Institute Inc, Cary, North Carolina).

Results

Of the 835 children originally eligible after 6 years of age, 15 withdrew, died, or otherwise were ineligible before the age of 18 years. Of the remaining 820, 40 were missing valid telephone numbers, 3 were in the military, 3 had disabilities precluding participation, and 2 were incarcerated, leaving a total of 722 eligible to complete study activities. A total of 424 children (50.8%) participated in both the 6- to 7-year and 18- to 20-year evaluations, which included BMI measurements at both visits. A total of 382 of these children participated in blood draw at 6 to 8 years. Participants were similar to the original cohort members not included in this analysis (n=411) with respect to sex, race, and parental history of asthma or allergy (Table 1). Of the 424 (204 males and 220 females), 46 females (20.9%) were classified as having an elevated BMI at the 6- to 7-year clinic visit compared with 47 males (23.9%) ($\chi^2 P=.60$). An association between BMI and environmental tobacco smoke was not present in our data.

Overall, 14 of 93 6- to 7-year-old study participants (15.1%) with elevated BMI had current asthma at their 18-year visit compared with 23 of 331 individuals (6.9%) with nonelevated BMI at 6 to 7 years of age (RR, 2.2; 95% CI, 1.2–4.0; $P=.02$). Male participants with elevated BMI at 6 to 7 years had higher rates of asthma as adults (5 of 47 [10.6%]) compared with males with nonelevated BMI (5 of 157 [3.2%]; RR, 3.3; 95% CI, 1.0–11.0; $P=.048$). There was a similar trend in females, with 9 of 46 (19.6%) with elevated BMI at 6 to 7 years of age having current asthma at 18 years of age vs 18 of 174 females (10.3%) with nonelevated BMI (RR, 1.9; 95% CI, 0.9–3.9; $P=.09$) (Table 2).

The aRR was then calculated to account for the role of concurrent atopy and obesity at 6 to 8 years of age. Current asthma as a young adult remained associated with elevated BMI at 6 to 8 years of age (aRR, 2.3; 95% CI, 1.2–4.1; $P=.008$), even after adjusting for early atopy (6–8 years of age). This relationship was stronger in males (aRR, 4.7; 95% CI, 1.4–16.2; $P=.01$) vs females (aRR, 1.7; 95% CI, 0.8–3.3; $P=.15$), although the estimates are somewhat imprecise (Table 3). The association between obesity and asthma also persisted when children diagnosed as having asthma before 6 years of age ($n=52$) were excluded from the analysis (eTable 1).

To further examine the association between overweight status in childhood and the presence of asthma in adulthood, the change in BMI between 6 to 7 years and 18 years of age was analyzed among those individuals for which BMI at both time points was available ($n=399$). Young adults were categorized by BMI change as follows: (1) persistently nonelevated BMI (nonelevated at both time points), (2) rising BMI (nonelevated BMI at 6–8 years of age and elevated BMI in adulthood), (3) decreasing BMI (elevated BMI at 6–8 years of age and nonelevated BMI in adulthood), and (4) persistently elevated BMI (elevated BMI at both time points). Individuals with a persistently nonelevated BMI classification were the reference group (Table 4). Individuals with an elevated BMI at both time points exhibited an increased risk of asthma (RR, 2.4; 95% CI, 1.2–4.7). However, those with an elevated BMI only as young adults did not have elevated risk for current asthma (RR, 0.8; 95% CI, 0.3–2.2), and those participants whose BMI decreased from childhood to adulthood were not at an increased risk of asthma in adulthood (RR, 0.8; 95% CI, 0.3–2.2) (Table 4). Results were similar by sex and after adjusting for atopy (data not shown).

Discussion

The preponderance of cross-sectional, epidemiologic evidence suggests that asthma is more prevalent in overweight and obese individuals.^{5–11} We demonstrate in a longitudinal analysis that obesity at a young age is associated with an increased risk of current asthma in adulthood, particularly among males. Furthermore, we found that the presence of longstanding elevated BMI from childhood into young adulthood may further increase the risk of current asthma in young adults. It is difficult to compare our findings with other studies given that few studies use a similar approach. In 2009, Scholtens et al²³ reported that children with a high BMI at 3 to 5 years of age but a normal BMI at 6 to 7 years had no increased risk of dyspnea at 8 years of age, yet children with a persistently elevated BMI between these ages had an increased odds of dyspnea at 8 years (odds ratio, 1.61; 95% CI, 1.03–2.52). Mamun et al¹⁹ reported that a positive change in BMI z score from 5 to 14 years of age was associated with symptomatic asthma at 14 years of age. They also showed an association that was stronger in males; however, a sex difference was not statistically significant. In contrast, Castro-Rodriguez et al²⁴ found no association between overweight status at 6 years of age and frequent wheezing at 11 years of age, although those who became overweight or obese between 6 and 11 years of age were more likely to develop asthma symptoms at 11 to 13 years of age.

In the Tucson Children's Respiratory Study, prepubertal obesity at 11 years of age among asthmatic children was an independent risk factor for persistent asthma at 16 years of age.²⁵ A prospective study of more than 9000 children 6 to 14 years of age found an increased risk of asthma for girls in the highest quintile of BMI at the onset of the study compared with those in the lowest quintile (RR, 2.24; 95% CI, 1.14–4.40; $P<.02$). Independent of the effect of BMI at entry, a greater risk of asthma was found for girls with the largest annual increase in BMI during the study (RR, 2.20; 95% CI, 1.13–4.28; $P<.05$).²⁶ In a prospective, Australian study, Burgess et al²⁷ found that young females with the highest BMI z score at

years of age were nearly 4 times as likely to present with adult-onset asthma compared with young females with the lowest BMI *z* scores.

Delineating the temporal relationship between weight status and asthma in the general pediatric population has been difficult because of the significant complexity and variability of pediatric growth and puberty and the limited number of longitudinal studies capable of describing these relationships. Our study was unique because we were able to take advantage of the longitudinal data (>10 years) by examining within-person change in BMI and its association with young adult asthma among a general population birth cohort.

A relevant limitation to studies examining the relationship of asthma and BMI is the possibility that obesity may confound the diagnosis of asthma due to frequent non-asthma-related dyspnea among those who are overweight. For instance, some reports have linked current obesity to decreased chest wall compliance, resulting in lower lung volumes, increased work of breathing, and increased energy costs related to breathing,²⁸ and other reports do not link obesity to increasing airway hyperreactivity.^{29, 30} Our findings suggest that long-standing elevated BMI in contrast to weight assessment at a single time point in early adulthood was a risk factor for asthma diagnosis. We are unable to determine whether the extended periods of observation while being overweight increased the risk of misdiagnosis or whether extended overweight status may contribute to the pathophysiology of asthma and onset of disease.

Our study has several other strengths and limitations. Because the study is based on a large population-based birth cohort, less selection bias can be anticipated compared with other study designs. The study population was relatively homogeneous, consisting of primarily middle socioeconomic status, suburban whites, and this may limit the degree to which the findings are generalizable to other populations. However, studying such a narrow population may also be considered a strength because it minimizes other sources of variability related to demographic and ethnic diversity. Although all children enrolled in the initial birth cohort did not participate at 18 to 20 years of age, there were no apparent important differences between those who participated vs those who did not, including family history of atopy and environmental tobacco exposure. In addition, with 37 children with current asthma, the power to detect differences may be lower than desired. Finally, we did not assess the severity of asthma in the study participants. The association of obesity and asthma severity is noteworthy because prior studies have reported that obese individuals with asthma are more difficult to treat and less responsive to corticosteroids.^{13, 31}

We conclude that an increased BMI at 6 to 8 years of age is associated with an elevated risk of physician-diagnosed asthma in adulthood, particularly among males, even when adjusting for atopy. Furthermore, overweight children at 6 to 8 years of age who are still overweight at 18 years of age have higher rates of asthma compared with those who are not overweight at 6 to 8 years and overweight at 18 years. The results of this study suggest that both the timing and duration of excessive weight gain may be important factors in increasing asthma risk. Future studies that delineate the mechanisms by which excessive weight increases asthma may provide important clues to the pathogenesis and effective management strategies for asthma in the obese population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Demographic comparison between included and excluded individuals

Characteristic	In study, No. (%) (n=424)	Not in study, No. (%) (n=411)	P value
Sex			.52
Female	220 (51.9)	204 (49.6)	
Male	204 (48.1)	207 (50.4)	
Race			.12
White	409 (96.5)	387 (94.2)	
Other than white	15 (3.5)	24 (5.8)	
Parental history of asthma and/or allergy ^a			.78
Yes	224 (54.6)	214 (53.6)	
No	186 (45.4)	185 (46.4)	
Elevated BMI at 6 years of age ^b			.53
Yes	93 (21.9)	11 (18.3)	
No	331 (78.1)	49 (81.7)	
Elevated BMI at 18 years of age ^c			.50
Yes	156 (39.1)	77 (36.3)	
No	243 (60.9)	135 (63.7)	
Teen tobacco use ^d			.51
Yes	83 (19.7)	44 (17.7)	
No	338 (80.3)	205 (82.3)	

Abbreviation: BMI, body mass index.

^a A total of 26 individuals with missing parental history information.^b A total of 351 individuals with missing information.^c A total of 224 individuals with missing information.^d A total of 165 individuals with missing information.

Table 2

Association between BMI at 6 to 8 years of age and current asthma at 18 years of age

Patient group	Current asthma at 18 years, No. (%)		RR (95% CI)	P value
	Elevated BMI at 6 years	Nonelevated BMI at 6 years		
All (n=424)	14 (15.1)	23 (6.9)	2.2 (1.2–4.0)	.02
Males (n=204)	5 (10.6)	5 (3.2)	3.3 (1.0–11.0)	.048
Females (n=220)	9 (19.6)	18 (10.3)	1.9 (0.9–3.9)	.09

Abbreviations: BMI, body mass index; CI, confidence interval; RR, relative risk.

Table 3

Multiple variable adjusted relative risk of adult asthma associated with BMI and atopy at 6 to 8 years of age

	aRR (95% CI)	P value
All participants (n=382) ^a		
Elevated BMI	2.3 (1.2–4.1)	.008
Atopic	3.3 (1.7–6.3)	<.001
Males only (n=186)		
Elevated BMI	4.7 (1.4–16.2)	.01
Atopic	5.0 (1.1–23.0)	.04
Females only (n=196)		
Elevated BMI	1.7 (0.8–3.3)	.15
Atopic	3.2 (1.5–6.5)	.002

Abbreviations: aRR, adjusted relative risk; BMI, body mass index; CI, confidence interval.

^a A total of 382 of 424 children participated in the blood draw at the 6- to 8-year visit.

Table 4

Relative risk of adult asthma by change in BMI status during 2 time points

BMI at 6–8 y/BMI at 18–20 y	Total No. (%) (n=399 ^a)	No. (%) with current asthma	RR (95% CI)	P value
Normal/normal	226 (56.6)	16 (7.1)	Referent	
Normal/high	84 (18.0)	5 (6.0)	0.8 (0.3–2.2)	.73
High/normal	17 (4.3)	1 (5.6)	0.8 (0.1–5.9)	.85
High/high	72 (21.1)	12 (16.5)	2.4 (1.2–4.7)	.02

Abbreviations: BMI, body mass index; CI, confidence interval; RR, relative risk.

^a A total of 399 of 424 individuals participated in BMI measurements at both the 6- to 8-year and 18- to 20-year visits.