

Dietary Intake, Physical Activity, Body Mass Index, and Childhood Asthma in the Third National Health and Nutrition Survey (NHANES III)

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Summary. Childhood asthma may be affected by dietary changes and increased body mass related to a sedentary lifestyle, although the mechanisms are poorly understood. To test this hypothesis, we used data from the National Health and Nutrition Survey (NHANES III) from 1988–1994, including 7,904 children. We analyzed cross-sectional information on body mass index (BMI = weight/height²), physical activity (hr/day viewing television), dietary intake (24-hr recall), and vitamin C intake (60 mg/day). The probability of self-reported asthma or wheezing relating to risk factors was calculated by logistic regression. After controlling for dietary intake, physical activity, and sociodemographic variables, asthma risk was three times higher for children aged 6–16 years in the highest percentiles of BMI (>95th percentile) when compared to children in percentiles 25–49 (OR = 3.44; 95% CI, 1.49–7.96). No increase was observed in children aged 2–5 years. Low vitamin C intake was marginally related to self-reported current wheezing in children aged 6–16 years. Our results show that increased BMI may influence asthma prevalence in children, but further investigation is needed. **Pediatr Pulmonol.** 2004; 38:31–42.

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Key words: childhood asthma; wheezing; body mass index; vitamin C.

INTRODUCTION

The large increase in the prevalence of asthma observed in most developed countries^{1,2} in recent years has occurred for unknown reasons, but the possible importance of a more sedentary lifestyle has been discussed.³ In some Western countries, the increased diagnosis of asthma in children has been accompanied by a similar increase in the prevalence of obesity.³ In the United States, the prevalence of self-reported asthma among children increased 75% during the period 1980–1994.⁴ During the same period, the distribution of body mass index (BMI) for children of the US showed an increasingly skewed upward shift,⁵ suggesting that common factors may be involved in the development of asthma and obesity. Carter and Platts-Mill recently proposed that the increasing incidence of asthma in Westernized countries might, in fact, be related to the increased prevalence of obesity.⁶ Previous reports suggested a potential association between BMI and asthma or wheezing.^{3,7–13} However, none of these studies considered total caloric intake and energy expenditure, which are strong determinants of energy balance and therefore BMI.¹⁵ In addition, some researchers hypothesized that changes in diet, such as decreased consumption of fresh fruits and vegetables and of unprocessed foods,^{16–19} contribute to asthma because the American diet has grown deficient in foods containing antioxidants.^{20,21} Recent

cross-sectional studies suggested that low consumption of vitamin C and fresh fruits is associated with increased asthma symptoms and decreased lung function in children.^{22,23} Dietary antioxidants, particularly vitamin C, could protect against the lung inflammation that results from both endogenous and exogenous oxidative reactions.²⁴ Asthmatic patients were reported to have lower than normal concentrations of vitamin C in their plasma and blood leukocytes, suggesting that asthma could be associated with chronically lower concentrations of

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vitamin C.^{25,26} To understand the mechanism by which BMI might affect the risk of asthma, the possible influences of dietary intake and energy expenditure need to be considered. A greater BMI could be associated with asthma, because asthmatic children may be less likely to exercise and have a poor diet, high in calories and low in “healthy” micronutrients such as vitamin C. Alternatively, the risk for a greater BMI and asthma could share common factors, unrelated to dietary intake and physical activity.

METHODS

In this study, we used data from the Third National Health and Nutrition Examination Survey (NHANES III) to evaluate the relationship between BMI, exercise, dietary intake, and self-reported childhood asthma and wheezing, taking into account potential confounding factors. NHANES III, being a cross-sectional study, allows us to analyze factors associated with prevalent asthma, and identify potential factors to be looked at in a prospective study. NHANES III was a health survey conducted between 1988–1994 among a sample representative of the noninstitutionalized civilian population of the United States aged ≥ 2 months old. National population estimates can be derived from the 6-year survey. Data were collected through household interviews and medical examinations. Details of the design and data collection methods were published.²⁷

There were 9,894 children aged 2–16 years who participated in NHANES III. Of those children, 7,851 (75.3%) had complete data for asthma, wheezing, vitamin C consumption, and BMI, and were included in the analysis; 2,043 (20.6%) had some missing information on one of these variables. Sample size varied for individual regression models due to the differing amounts of missing data for additional covariates. Information on covariates was obtained from the questionnaire and was defined as follows.

Asthma

The asthma variable was based on a positive response by a proxy (usually a parent or guardian) to two questionnaire items, “Did a doctor ever say that [child’s name] had asthma?” and, “Does [child’s name] still have asthma?” The resulting variable is referred to in the text as self-reported current asthma.

Wheezing

The wheezing variable was based on a combination of two questionnaire items. Children were said to exhibit wheezing if their proxy answered that they experienced wheezing or whistling in the chest at any time in the past 12 months, and if a child’s chest ever sounded wheezy or

whistled when the child did not have a cold. The resulting variable is referred to in the text as self-reported wheezing.

Body Mass Index

BMI was based on measurements of weight and standing height [weight in kg/(standing height in meters)²] recorded during the medical examination for each child. BMI is independent of stature and correlates well with the relative size of body fat stores in children and adolescents,^{28,29} but changes with age.¹⁴ Therefore it is important to categorize BMI over small age ranges. We used the Centers for Disease Control (CDC) age- and sex-specific benchmarks to determine BMI percentile for each subject.³⁰ This classification in percentiles of BMI was further regrouped for children aged 2–5 years and children aged 6–16 years for the analyses. Parental BMI was calculated using the reported height and weight of each parent.

Physical Activity

To estimate physical activity, we used the response to the question: “About how many hours did [child’s name] watch TV yesterday?” This question was not asked for children < 4 years old and for some of the older children. We classified this variable as ≤ 3 hr per day, ≥ 4 hr per day, or “unknown.” Television watching was shown to be a good surrogate for physical activity, and to be inversely associated with HDL cholesterol and apolipoprotein A1, substances that are positively associated with physical activity.³¹

Atopy

Trained health technicians administered skin tests on children ≥ 6 years old. All measurements were taken within the acceptable time of 15 ± 5 min after the administration of the allergens and controls. Children with prior severe reaction to skin prick tests or severe asthma or respiratory symptoms did not have these tests ($n = 1,074$, or 23.8%). Children were classified as atopic if they had wheals of 3 mm or greater more than the negative control (saline) to any of the ten skin tests (white oak, cat, house dust mite, *Alternaria*, rye grass, peanut, Russian thistle, German cockroach, Bermuda grass, or ragweed).

Dietary Intake

Dietary interviews were administered to all examinees by a trained dietary interviewer. Respondents reported all foods and beverages consumed (except plain drinking water) for the previous 24-hr time period (midnight to midnight). Proxies responded for children 2–5 years old, and for others who were unable to report on their own. Although it was not required, many interviews for respondents 6–11 years old were completed by proxy or with the child and a proxy.

Vitamin C Consumption

Our measurement of vitamin C consumption was derived from two NHANES III sources: the 24-hr food recall and the household questionnaire.³² The household questionnaire provided information regarding vitamin and mineral consumption in the past month. Proxies responded for children 2–16 years old. If a participant reported any vitamin or mineral use in the past month, they were questioned further regarding dosage and frequency of consumption. Vitamin C consumption was used as a dichotomous variable, using 60 mg/day (the current US RDA)³³ as the cutoff point in our analysis.

Sociodemographic Variables and Other Covariates

Age at time of interview was categorized as 2–5 years old, 6–11 years old, or 12–16 years old. Race was categorized as either black, white, Mexican-American, or other. The “other” race category was too small to be analyzed separately, so those children were deleted from models that included race as a covariate. Respondents were classified as being above or below the poverty level, based on their poverty income ratio (PIR). The PIR is calculated by family income and family size using tables published yearly by the Census Bureau, taking into account geographic location, inflation rate, and family size. Based on 1990 data, a family of 4 with an income less than \$16,000 would be considered poor (PIR <1). Low-income status was defined as PIR <1.3. Dichotomous variables were included to indicate whether there was a cigarette smoker in the child’s home and whether either parent had asthma or hay fever at any age.

Analysis

We determined the association between the probabilities of self-reported asthma or wheezing and individual covariates including BMI, gender, race, parental asthma and hay fever, passive smoking, poverty level, presence of atopy, number of hours spent watching television, vitamin C intake, and total caloric intake, using univariate logistic regression models. We then used multivariate logistic models to estimate the association between the probabilities of self-reported asthma or wheezing and these same covariates. We determined predictors of BMI using a linear regression model and the same covariates, with the additional covariate of maternal and paternal BMI. In these regression models, the beta coefficient provides the change in BMI related to the change of category (in comparison with the reference) or to the change in one unit of the predictor variable (for continuous variables). All analyses were done using SUDAAN, a statistical package compatible with SAS. SUDAAN is able to account for both the complex survey design and the weights used in

NHANES III.²⁷ We present results stratified by age groups (2–5 years and 6–16 years), because the predictors of self-reported asthma and wheezing differed between these age groups (but not within the older group).

RESULTS

In total, 7,851 children aged 2–16 years were included in our analysis. From the original sample ($n = 9,894$), 2,043 children were excluded because of missing data on asthma, wheezing, vitamin C consumption, or anthropometric measurements. Major characteristics of the children included and excluded from the current analysis are presented in Table 1. Children excluded from the analysis were younger, and had a higher prevalence of asthma diagnosis; however, other characteristics were similar in both groups.

Self-reported asthma and wheezing were higher among older children (7.3% vs. 4.6% for asthma, and 7.7% vs. 6.6% for wheeze; Table 2). Reported parental asthma or allergy was similar in both age groups. Among older children, 34.4% reported watching television for 4 hr or more per day. Low vitamin C intake (<60 mg/day) was more prevalent in the younger children.

The cross-classification of self-reported current asthma and current wheezing showed that among children aged 2–5 years, 71.6% of those with current asthma reported current wheezing, and 52.1% of those with current wheezing reported current asthma. Among children aged 6–16 years, 77.4% of those with current asthma reported current wheezing, and 73.1% of those with current wheezing reported current asthma.

In the univariate models (Table 3), we observed that among children aged 2–5 years, the risk of self-reported asthma was significantly associated with race, parental asthma or hay fever (OR = 2.67; 95% CI, 1.56–4.57), poverty level (OR = 1.92; 95% CI, 1.15–3.20), and television watching (OR = 3.02; 95% CI, 1.14–8.05 for 4 hr or more vs. 3 hr or less). BMI was not associated with risk of self-reported asthma in either the univariate (OR = 1.90; 95% CI, 0.78–4.63 for children over the 95th percentile vs. 25–49th percentiles) or multivariate models (OR = 1.41; 95% CI, 0.56–3.57).

Among children aged 6–16 years, self-reported asthma was significantly related to BMI (OR = 3.31; 95% CI, 1.44–7.60 for children over the 95th percentile vs. 25–49th percentiles), parental asthma or hay fever (OR = 3.76; 95% CI, 2.50–5.0), and atopy (OR = 3.07; 95% CI, 1.55–6.07) in the univariate models (Table 4). In the multivariate model, results remained similar. Children over the 95th percentile of BMI had more than three times the risk of self-reported asthma than children in the 25–49th percentiles (OR = 3.44; 95% CI, 1.49–7.96).

Self-reported wheezing among children aged 2–5 years was significantly higher among Mexican American and

TABLE 1—Population Characteristics Among NHANES III Examination Participants Aged 2–16 Years (n = 7,851) and Excluded (n = 2,043) From Current Analysis

Variable	Subjects included in current analysis		Subjects excluded from current analysis			
	N	Weighted %	N	Weighted %		
Age						
2–5 years old	3,337	25.5	1,192	37.8		
6–11 years old	2,759	41.0	527	36.0		
12–16 years old	1,755	33.5	324	26.2		
Gender						
Male	3,821	50.7	1,047	53.6		
Female	4,030	49.3	996	46.4		
Race						
White	2,070	64.8	602	67.5		
Black	2,678	16.1	602	13.5		
Mexican American	2,727	9.0	736	8.9		
Other	376	10.1	103	10.0		
Asthma						
Yes	415	6.6	186	10.0		
No	7,436	93.4	1,605	75.2		
Missing			252	14.8		
Wheeze, last 12 months						
Yes	561	7.4	83	3.5		
No	7,290	92.6	193	37.1		
Missing			1,167	59.4		
Parental asthma or hay fever						
Yes	1,367	24.3	424	28.4		
No	6,323	73.9	1,592	69.5		
Missing	161	1.8	27	2.1		
Smoker in house						
Yes	3,085	39.5	826	41.9		
No	4,766	60.5	1,210	58.1		
Poverty level						
Below	2,945	23.5	771	25.3		
Above	4,258	71.1	1,114	70.4		
Missing	648	5.4	158	4.3		
Atopy						
Yes	1,479	33.3	300	20.0		
No	1,961	23.6	282	21.7		
Excluded	4,411	43.1	1,461	58.3		
Television watching						
≤3 hr	3,141	52.4	614	43.7		
≥4 hr	2,124	27.9	471	26.3		
Unknown	2,586	19.6	958	30.0		
Vitamin C intake						
≥60 mg/day	2,248	29.9	381	20.5		
<60 mg/day	5,603	70.1	1,033	52.6		
Missing			629	26.9		
	N	Mean	SD	N	Mean	SD
Age at interview	7,851	7.62	4.34	2,043	6.24	4.11
BMI	7,851	18.12	4.13	1,880	17.68	3.78
Weight	7,851	32.07	19.16	1,972	1.77	0.80
Height (standing)	7,851	126.89	26.17	1,965	50.72	0.42
Total kcals intake/day	7,851	1.84	0.80	1,361	1.97	0.04

black children. Parental history of asthma or hay fever was also significantly related to wheezing in both the univariate and multivariate models (Table 5). Increased BMI was not significantly associated with wheezing in

either of these models (OR = 1.29; 95% CI, 0.57–2.92; and OR = 1.09 95%; CI, 0.47–2.48, respectively).

Among children 6–16 years, the risk of self-reported wheezing was significantly related to BMI. Children over

TABLE 2—Population Characteristics of Subjects Included in Analysis (n = 7,851), Stratified by Age Group

	Age 2–5 years		Age 6–16 years			
Variable	N	Weighted %	N	Weighted %		
BMI ¹						
<25	657	20.2	779	188		
25–49	749	23.4	977	23.7		
50–84	1,267	40.0	1,508	33.3		
85–95	370	9.7	645	13.8		
>95	294	6.8	605	11.0		
Gender						
Male	1,624	50.2	2,197	50.8		
Female	1,713	49.8	2,317	49.1		
Race						
White	906	61.2	1,164	66.0		
Black	1,072	16.6	1,606	16.0		
Mexican American	1,182	10.0	1,545	8.7		
Other	177	12.2	199	9.4		
Asthma						
Yes	158	4.6	257	7.3		
No	3,179	95.4	4,257	92.7		
Wheeze, last 12 months						
Yes	266	6.6	295	7.7		
No	3,071	93.4	419	92.3		
Passive smoking						
Yes	1,272	37.6	1,823	40.2		
No	2,065	62.4	2,701	59.8		
Parental asthma or hay fever						
Yes	595	24.3	773	24.3		
No	2,694	74.5	3,629	73.7		
Missing	48	1.3	113	2.0		
Poverty level						
Below	1,300	26.2	1,645	22.6		
Above	1,760	68.3	2,498	72.0		
Missing	277	5.5	371	5.4		
Atopy						
Yes			1,961	44.7		
No			1,479	34.4		
Excluded			1,074	23.6		
Television watching						
≤3 hr	475	16.5	2,666	64.7		
≥4 hr	313	9.1	1,811	34.4		
Unknown	2,549	74.8	37	0.9		
Vitamin C intake						
≥60 mg/day	819	23.4	1,429	32.3		
<60 mg/day	2,518	76.6	3,085	67.7		
	N	Mean	SD	N	Mean	SD
Age at interview	337	3,046.0	(1.12)	4,514	10.69	(3.08)
BMI	3,337	16.12	(1.82)	4,514	19.60	(4.70)
Weight (pounds)	3,337	16.83	(3.82)	4,499	43.34	(18.15)
Height (inches)	3,337	101.70	(9.51)	4,547	145.52	(17.65)
Total kcal int/day	3,337	1.55	(0.56)	4,555	2.05	(0.89)

¹Use and interpretation of CDC growth charts. From Vital and Health Statistics of the Centers for Disease Control and Prevention. National Center for Health Statistics. 2000, number 314.

the 95th percentile of BMI had twice the risk of self-reported wheezing than children in the 25–49th percentiles (OR = 2.29; 95% CI, 1.4–4.61). Parental asthma or hay fever (OR = 3.67; 95% CI, 2.36–5.72) and atopy were

also related to self-reported wheezing, but not watching television (OR = 1.06; 95% CI, 0.73–1.54), in the univariate models. White children were more likely to report wheezing than were children from other races. Low

TABLE 3—Predictors of Self-Reported Current Asthma for Children Aged 2–5 Years

Variable	Univariate model		Multivariate model	
	OR	95% CI	OR	95% CI
BMI (percentiles)				
<25	0.83	0.40–1.73	0.83	0.38–1.81
25–49	1.0	1.0	1.00	1.00
50–84	1.79	0.96–3.35	1.89	1.01–3.52*
85–94	0.55	0.20–1.51	0.58	0.21–1.63
>95	1.90	0.78–4.63	1.41	0.56–3.57
Gender				
Male	1.17	0.68–2.02	1.26	0.74–2.14
Female	1.00		1.00	
Race				
Black	1.97	1.24–3.14*	1.95	1.15–3.31*
Mexican American	0.89	0.50–1.57	1.03	0.51–3.31
Other	1.99	0.93–4.26	2.19	1.02–4.70
White	1.00		1.00	
Parental asthma or hay fever				
Yes	2.67	1.56–4.57*	3.24	1.90–5.52*
No	1.00		1.00	
Passive smoking				
Yes	1.50	0.84–2.68	1.34	0.77–2.51
No	1.00		1.00	
Poverty level				
Below	1.92	1.15–3.20*	1.54	0.96–2.45
Unknown	1.32	0.47–3.66	1.38	0.52–3.72
Above	1.00		1.00	
Television watching				
≤3 hr	1.00		1.00	
≥4 hr	3.02	1.14–8.05*	2.67	0.97–7.31
Unknown	0.87	0.41–1.85	0.71	0.30–1.68
Vitamin C intake				
<60 mg/day	1.56	0.90–3.26	1.58	0.91–2.76
≥60 mg/day	1.00		1.00	
Caloric intake (per 1,000 calories)	1.25	0.86–1.95	1.19	0.70–2.00
Age (per year)	1.24	0.96–1.59	0.94	0.72–1.23

* $P < 0.05$.

vitamin C intake was marginally related to the risk of self-reported wheeze (OR = 1.36; 95% CI, 0.95–1.95). Similar results were observed in the multivariate model (Table 6).

When we evaluated the predictors of increasing BMI using linear regression models, we observed that among children aged 2–5 years, a higher BMI was related to being Mexican American (compared to white children, Mexican American children had a BMI higher by 0.20 on average) and a higher parental BMI (an increase of 1 unit in a mother's BMI was related to an increase of 0.07 on average in her child's BMI). Among older children aged 6–16 years, a higher BMI was related to being Mexican American, being exposed to passive smoking, watching television for 4 hr or more per day (children watching television more than 4 hr per day had a BMI higher by 0.93 on average than their counterparts), higher parental BMI (an increase of 1 unit in a mother's BMI was related to an increase of 0.21 on average in her child's BMI), and lower

vitamin C intake (children with intake of vitamin C <60 mg/day had a BMI higher by 0.53 than children with vitamin C intake over 60 mg/day) (Table 7).

DISCUSSION

In this study, we found that a higher BMI was associated with an increased risk of self-reported current asthma and wheezing in children aged 6–16 years old, but not in younger children. This association persisted after accounting for number of hours watching television, a proxy for lack of physical activity, and energy intake. This suggests that body fat per se may play a role in the prevalence of asthma, although the cross-sectional nature of our study and the exclusion of subjects because of missing data limit the interpretation.

Data from NHANES III showed that the US population is becoming more obese,³⁴ and other data show that asthma prevalence in the US has increased over the past

TABLE 4—Predictors of Self-Reported Current Asthma for Children Aged 6–16 Years

Variable	Univariate model		Multivariate model	
	OR	95% CI	OR	95% CI
BMI (percentiles)				
<25	1.21	0.57–2.60	1.26	0.54–2.97
25–49	1.0		1.0	
50–84	1.43	0.77–2.66	1.36	0.69–2.69
85–95	1.77	0.94–3.33	1.83	0.92–3.66
>95	3.31	1.44–7.60*	3.44	1.49–7.96*
Gender				
Male	1.07	0.76–1.51	0.98	0.68–1.40
Female	1.00		1.00	
Race				
Black	0.89	0.59–1.33	0.94	0.64–1.37
Mexican American	0.67	0.37–1.25	0.74	0.40–1.39
White	1.00		1.00	
Other	0.63	0.28–1.45	0.65	0.27–1.59
Parental asthma or hay fever				
Yes	3.76	2.50–5.66*	3.50	2.22–5.51*
No	1.00		1.00	
Passive smoking				
Yes	0.99	0.59–1.66	0.90	0.56–1.45
No	1.0		1.0	
Poverty level				
Below	0.97	0.60–1.55	1.15	0.70–1.88
Unknown	0.56	0.19–1.63	0.71	0.23–2.16
Above	1.00		1.00	
Atopy				
Yes	3.07	1.55–6.07*	2.83	1.37–5.87*
No	1.00		1.00	
Not done	3.18	1.42–7.13*	3.31	1.50–7.28*
Television watching				
≤3 hr	1.00		1.00	
≥4 hr	0.94	0.63–1.40	0.88	0.59–1.31
Unknown	1.69	0.34–8.51	1.90	0.44–8.27
Vitamin C intake				
<60 mg/day	1.04	0.69–1.56	1.04	0.69–1.59
≥60 mg/day	1.00		1.00	
Caloric intake (per 1,000 calories)	0.88	0.70–1.12	0.80	0.58–1.10
Age (per year)	1.03	0.96–1.11	1.02	0.95–1.10

* $P < 0.05$.

20 years.² It remains unknown whether these two observations are related. Cross-sectional studies suggested that body fat may be related to prevalence of wheezing in children; however, results are inconsistent.³ Siersted et al.³⁵ suggested that some might be related to the underdiagnosis of mild asthma in fatter children. A recent analysis of the National Study of Health and Growth by Chinn and Rona suggests that the increasing trend in being overweight and obese does not explain the increase in asthma among British children, and that the association between obesity and asthma is of recent origin.³⁶ One challenge for understanding the impact of BMI on asthma or wheezing is determining the relationship between energy intake, diet composition, and energy expenditure. Most previous studies did not account for dietary intake

and physical activity, which may have confounded the association. If energy intake is maintained at a constant level, lower levels of physical activity will relate to a higher BMI,³⁷ and low physical activity was proposed as a risk factor for asthma. Platts-Mills et al.³⁸ suggested that the reduction in deep breathing associated with a sedentary lifestyle may lead to airway narrowing, by reducing the extent to which bronchial smooth muscle is stretched. Obese subjects tend to have decreased pulmonary volumes and less thoracic wall distensibility, and are more likely to have bronchial hyperresponsiveness than children who are not obese.³⁹ Obese children report more symptoms such as coughing, wheezing, and dyspnea than nonobese children, in subgroups both with and without asthma.⁴⁰ One hypothesis for these findings is that

TABLE 5—Predictors of Self-Reported Wheeze in Last 12 Months for Children Aged 2–5 Years

Variable	Univariate model		Multivariate model	
	OR	95% CI	OR	95% CI
BMI				
<25	0.60	0.31–1.18	0.62	0.31–1.22
25–49	1.00		1.00	
50–84	1.02	0.58–1.79	1.05	0.63–1.75
85–95	0.81	0.37–1.79	0.81	0.37–1.80
>95	1.29	0.57–2.92	1.09	0.47–2.48
Gender				
Male	1.42	0.90–2.25	1.49	0.96–2.31
Female	1.00		1.00	
Race				
Black	1.78	1.20–2.64*	1.72	1.10–2.67*
Mexican American	1.80	1.25–2.58*	1.95	1.23–3.10*
Other	1.62	0.70–3.72	1.72	0.72–4.11
White	1.00		1.00	
Parental asthma or hay fever				
Yes	2.31	1.47–3.65*	2.77	1.76–4.36*
No	1.00		1.00	
Passive smoking				
Yes	1.30	0.76–2.24	1.25	0.71–2.20
No	1.00		1.00	
Poverty level				
Below	1.81	1.13–2.90*	1.48	0.89–2.46
Above	1.00		1.00	
Unknown	1.39	0.71–2.72	1.33	0.68–2.58
Television watching				
≤3 hr	1.00		1.00	
≥4 hr	2.38	0.89–6.36	2.12	0.78–5.75
Unknown	1.34	0.62–2.89	0.86	0.37–1.99
Vitamin C intake				
<60 mg/day	1.39	0.90–2.14	1.37	0.87–2.16
≥60 mg/day	1.00		1.00	
Caloric intake (per 1,000 calories)	0.91	0.67–1.23	0.99	0.72–1.36
Age in years	0.95	0.75–1.20	0.82	0.62–1.08

* $P < 0.05$.

increased bronchial responsiveness leads to the avoidance of exercise and a positive energy balance; another hypothesis is that the lack of exercise leads to low sympathetic airway tone.^{41–43}

In addition to hypotheses related to exercise, others suggested that estrogens are a risk factor for asthma, particularly in women.⁸ A recent study conducted in Taiwan reported that the prevalence of past wheeze rose with increasing BMI in girls aged 13–14 years, but not in boys.⁴⁴ Camargo et al., in a large cohort of nurses, reported that the risk of developing an incident case of asthma was associated with increasing BMI after adjusting for energy intake and physical activity.⁴⁵ Obesity was associated with higher levels of bioavailable estrogen in pre- and post-menopausal women, and could explain these findings.^{46,47} In our study, BMI was positively related to physician-diagnosed asthma and wheezing in older children (6–16 years old); we did not observe a difference according to gender, although we could not evaluate incident cases of

asthma or estrogen levels. Figure 1 presents the potential interaction between BMI, physical activity, diet and other factors, and asthma.

A significant association of BMI and asthma was observed among children aged 6–16 years but not among younger children (aged 2–5 years). This might be due to the smaller number of cases observed in this younger age group, as well as the fact that the diagnosis of asthma in younger children is less accurate than in older children and might lead to more substantial misclassification, especially in children under 4 years old. In addition, if hormones play a role, it might be more easily observed in older children. For both age groups (2–5 and 6–16 years), the stronger risk factors were a parental history of asthma or hay fever, which confirms the genetic component of asthma. This association was stronger in the older age group (6–16 years) which suggests, as mentioned earlier, that a medical diagnosis of asthma might be less accurate in younger children. Atopy defined by a reactive skin test

TABLE 6—Predictors of Self-Reported Wheeze in Last 12 Months for Children Aged 6–16 Years

Variable	Univariate model		Multivariate model	
	OR	95% CI	OR	95% CI
BMI				
<25	1.26	0.70–2.26	1.22	0.64–2.33
25–49	1.0	1.0	1.0	1.0
50–84	1.17	0.67–2.05	1.03	0.58–1.85
85–95	1.42	0.84–2.40	1.34	0.75–2.41
>95	2.29	1.14–4.61*	1.98	1.0–3.92*
Gender				
Male	1.05	0.77–1.44	0.99	0.72–1.36
Female	1.00		1.00	
Race				
Black	0.77	0.52–1.12	0.82	0.56–1.21
Mexican American	0.78	0.52–1.16	0.92	0.60–1.41
Other	0.34	0.12–0.97	0.35	0.12–1.07
White	1.00		1.00	
Parental asthma or hay fever				
Yes	3.67	2.36–5.72*	3.42	2.11–5.54*
No	1.00		1.00	
Passive smoking				
Yes	1.09	0.67–1.77	1.01	0.65–1.59
No	1.00		1.00	
Atopy				
Yes	2.75	1.52–4.97*	2.72	1.48–5.00*
No	1.00		1.00	
Not done	2.28	1.06–4.89*	2.34	1.09–5.00*
Poverty level				
Below	0.78	0.49–1.24	0.95	0.59–1.52
Above	1.00		1.00	
Unknown	0.72	0.30–1.73	0.90	0.35–2.30
Television watching				
≤3 hr	1.00		1.00	
≥4 hr	1.06	0.73–1.54	1.06	0.72–1.57
Unknown	0.56	0.15–2.12	0.52	0.12–2.27
Vitamin C intake				
<60 mg/day	1.36	0.95–1.95	1.38	0.92–2.08
≥60 mg/day	1.00		1.00	
Caloric intake (per 1,000 calories)	0.97	0.80–1.16	0.92	0.74–1.13
Age (in years)	1.04	0.98–1.11	1.02	0.95–1.10

* $P < 0.05$.

was also a strong risk factor for asthma among children aged 6–16 years. Children who did not receive the skin test because of a severe previous reaction or severe asthma had the larger risk of asthma, suggesting that this group included a large proportion of asthmatics.

Self-reported wheezing was also associated with BMI in children 6–16 years old. This association is likely to be underestimated because of the potential misclassification on the classification of asthma based on reported wheezing.

Dietary factors, such as a low intake of antioxidants and omega 3 fatty acids, may affect the risk of wheezing and asthma.¹⁹ Two recent studies conducted in children reported that the intake of fruits with a high vitamin C content was related to a decrease in the risk of wheezing

and lower pulmonary functions.^{22,23} Vitamin C is a major antioxidant present in the airway surface liquid of the lung. It contributes to antioxidant activity by scavenging the superoxide radical ($O_2^{\cdot-}$) and affecting arachidonic acid metabolites, in particular PGF $_{2\alpha}$ -induced bronchoconstriction. It also plays a role in immune function and could modulate the biological response to viral infections.^{18,19,24} Vitamin C consumption (≥ 60 mg/day) was not significantly protective against asthma in this analysis; however, current wheezing was marginally related to lower vitamin C intake in children 6–16 years old, which is concordant with prior studies.^{22,23} In addition, the measurement of vitamin C consumption used in this survey was based on 24-hr food recall and may not accurately reflect usual vitamin C intake, leading to some

TABLE 7—Predictors of Increasing Body Mass Index for Children Aged 2–5 and 6–16 years (Multivariate Models)

Variable	Age 2–5			Age 6–16		
	Beta	SE	P	Beta	SE	P
Sex						
Male	−0.03	0.09	0.72	0.06	0.19	0.76
Female	0.00			0.00		
Race						
Black	−0.30	0.09	0.00	−0.29	0.27	0.29
Mexican American	0.20	0.09	0.023	0.01	0.29	0.05
Other	0.45	0.28	0.12	−0.93	0.29	0.00
White	0.00			0.00		
Passive smoking						
Yes	0.19	0.14	0.18	0.82	0.30	0.01
No	0.00			0.00		
Poverty						
Yes	0.15	0.09	0.13	0.28	0.33	0.39
No	0.00			0.00		
Unknown	0.21	0.18	0.25	0.33	0.40	0.41
Television watching						
≤3 hr	0.00			0.00		
≥4 hr	0.17	0.19	0.37	0.93	0.25	0.005
Unknown	−0.24	0.18	0.19	0.52	0.54	0.33
Maternal BMI	0.07	0.01	0.00	0.21	0.04	0.00
Paternal BMI	0.07	0.01	0.00	0.14	0.02	0.00
Caloric intake	0.03	0.14	0.82	−0.22	0.12	0.07
Vitamin C intake						
<60 mg/day	0.02	0.10	0.85	0.53	0.25	0.04
≥60 mg/day	0.00			0.00		
Age	−0.23	0.08	0.01	0.69	0.04	0.00

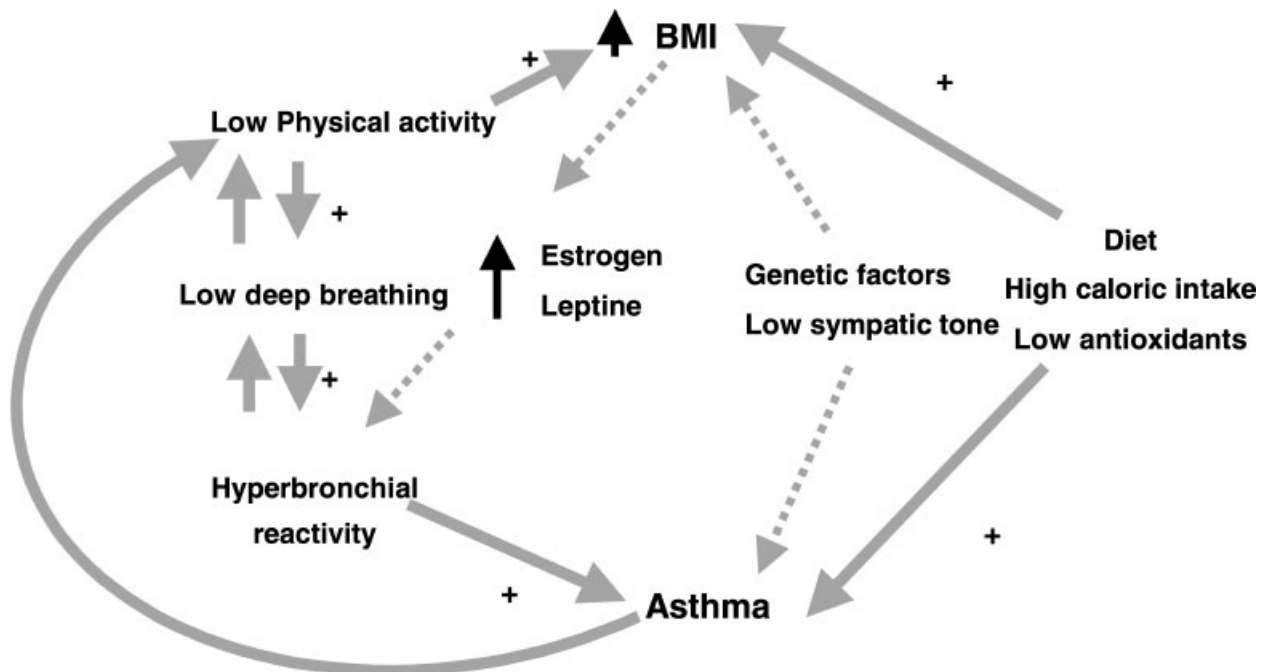


Fig. 1. Interrelationship of BMI, physical activity, diet and other factors, and asthma. High caloric intake and low physical activity are positively related to BMI. Low antioxidant intake was related to asthma. Low physical activity leads to low deep breathing and increased hyperbronchial reactivity and asthma. Also, hormonal factors such as estrogen and leptine might be increased in women with higher BMI, and could be a risk factor for hyperbronchial reactivity. Asthma and obesity could share common genetic factors.

misclassification and underestimation of the effect.^{48,49} Our results on the association of self-reported current asthma and BMI are consistent with those of a previous analysis of NHANES III in children aged 4–17 years;¹³ however, in that analysis, the authors did not account for several factors that might have confounded this association, including major predictors of BMI: total caloric intake, vitamin C intake (as a marker of a healthy diet), and hours of watching television (as a marker of physical activity). In addition, parental history of asthma and allergy was not accounted for. Based on our analysis, one of the strongest predictors of asthma was parental allergy or asthma. Children's BMI was also strongly related to their parents' BMI, which could reflect genetic susceptibility and the impact of lifestyle factors, such as low physical activity and poor diet. This suggests that obesity and asthma may share common genetic or environmental risk factors. Our results also suggest that the time spent indoors watching television may play a role in the risk of asthma and wheezing in the youngest group (aged 2–5 years), although this information was available only on a small subset of our sample (23.4%). We used time watching television as a surrogate measurement for physical activity, but it may also reflect more potential exposure to indoor allergens because of more time spent indoors. Some misclassification of this variable, which only reported the previous day of television watching and not a "typical" day, might have resulted in an underestimate of the importance of this association.

Because this analysis used cross-sectional data, it is not known whether the onset of asthma followed the onset of obesity. Others reported results similar to ours, suggesting an association between obesity and childhood asthma and wheezing. Whether the mechanism is related to a reduction in airway caliber, to low sympathetic tone and enhanced parasympathetic activity, to an alteration in lipid metabolism, or to other factors is not clear.^{3,50} Prospective data are needed to determine if such an association is causal and if there is a time frame for being at major risk for asthma development during childhood.

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