Is Obesity Associated With Early Sexual Maturation? A Comparison of the Association in American Boys Versus Girls

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ABSTRACT. *Background.* Increasing evidence suggests a close association between early sexual maturation (SM) and obesity in girls and female adults. Earlier maturing girls are more likely to be obese than nonearly maturers. However, limited research has been conducted in boys.

Objective. To examine the influence of early SM on fatness in boys and compare it with girls, and to test the hypothesis that the associations differ by gender because of the differences in growth and SM patterns in boys and girls.

Study Design. Cross-sectional study.

Subjects. One thousand five hundred one girls and 1520 boys (aged 8–14 years) who participated in the Third National Health and Nutrition Examination Survey survey (1988–1994) and had complete anthropometry (weight, height, skinfold thickness) and SM data.

Methods. Based on each individual's age and SM status (Tanner stages: genitalia stages for boys and breast stages for girls), the subjects were classified as: 1) early maturers (those who reached a certain Tanner stage earlier than the median age for that stage), and 2) the others (average and later maturers). Overweight was defined as a body mass index (BMI) ≥85th percentile, and obesity ≥95th percentile. Logistic regression analysis was to test how early maturation affected the risks for overweight and obese. Using multiple linear regression models, the associations between fatness (BMI and skinfold thickness) and SM were systematically examined. Covariates including age, ethnicity, residence, family income, energy intake, and physical activity were adjusted.

Results. Early SM was positively associated with overweight and obesity in girls, but the associations were reverse for boys. The prevalence of overweight in early maturers versus the others was 22.6% versus 31.6% in boys and 34.4% versus 23.2% in girls; the figures for obesity were 6.7% versus 14.8% and 15.6% versus 8.1%, respectively. Odd ratios and 95% confidence intervals for obesity were 0.4 (0.2, 0.8) for boys and 2.0 (1.1, 3.5) for girls, and covariates were adjusted. Most significant differences in overweight and obesity among ethnic groups disappeared after controlling for SM. Fatness (BMI and skinfold thickness) was associated with SM stages and with early maturation in boys and girls, but the associations were in opposite directions. Compared with their counterparts, early maturing boys were thinner, whereas early maturing girls were fatter.

Conclusions. Obesity is associated with sexual maturation in both boys and girls, but the association differs. There is positive association in girls, but a negative one in boys. Maturation status should be taken into consideration when assessing child and adolescent obesity. *Pediatrics* 2002;110:903–910; *child, adolescent, fatness, body mass index, obesity, overweight, sexual maturation.*

ABBREVIATIONS. SM, sexual maturation; BMI, body mass index; NHANES III, Third National Health and Nutrition Examination Survey; CDC, Centers for Disease Control and Prevention; SES, socioeconomic status; CI, confidence interval; OR, odds ratio.

The increase of obesity in children and adolescents has become a major public health concern in the United States and worldwide.[1–3] Studies show that obesity is associated with sexual maturation (SM) among adolescent girls and young female adults.[4–17] Most recently, using data from a school-based national representative sample in the United States (the National Longitudinal Study of Adolescent Health), Adair and Gordon-Larsen[4] found that early maturing adolescent girls were almost twice as likely to be overweight than average-maturing girls. Although the causal direction of this association remains controversial,[7,8,18–23] a growing body of evidence suggests that SM has a more important effect on levels of fatness than fatness does on the timing of SM.[9–12,17] Fatness and body mass index (BMI = wt/ht²) have been found to be more closely correlated with maturation stage (or development age) than chronological age among girls.[6,12]

Limited research has been conducted in boys and male adults to study the association between SM and obesity. This is particularly attributable to the difficulties of measuring SM in males in epidemiologic research. A systematic examination of the association in boys and comparison of it to girls will provide useful insights to advance our understanding of the controversial relationship between SM and obesity. A good understanding of the relationship between SM and obesity has many important clinical and public health implications. For example, it can help refine and develop appropriate anthropometry references (eg, BMI cutoffs) for child and adolescent obesity[13,24,25]; second, it can guide the targeting of efforts and resources in the prevention and management of child and adolescent obesity.

Studies from the United States and other industrialized countries and developing countries provide strong evidence of the secular trends of SM among adolescents.[26–29] Recently, based on findings from

females, some scholars warned that with the secular trends of early maturation, the obesity epidemic in American children and adolescents will become even more alarming. However, it is not clear whether this is true for males. The literature has documented remarkable gender differences in growth and SM patterns, particularly during puberty.[26,30,31] Nevertheless, the continuing secular changes in SM observed in the United States and in other populations over the past 2 decades suggest the need to examine their impacts on individuals' health (eg, obesity) and well-being.

For epidemiologic studies of SM and fatness, a big challenge is to find good measures of SM and appropriate approaches to classify the timing of SM (ie, to categorize early, average, and late maturers). In previous studies, age at menarche was predominately used as the indicator of SM, and as a result, males and girls at young ages could not be included. Although age at menarche has been widely used as an indicator of females' SM and is easy and cheap to collect,[25,26] there are a few additional limitations when using it to study the relationship between SM and fatness. Usually menarcheal age is reported in whole years, and as a result, individuals' SM cannot be classified precisely (eg, 2 girls are not differentiated if 1 has menarche at the beginning of age X and the other, at the end of age X). In addition, recall errors are of concern. Another major gap in the literature is that most previous studies addressing the influence of SM on obesity fail to adjust for potential confounders such as diet and physical activity.

Using the Third National Health and Nutrition Examination Survey (NHANES III) data collected in the United States during 1988–1994,[32] we examined the association between SM and obesity among boys, and compared it with girls. We were able to include both boys and girls, old children (before puberty), and adolescents with our proposed approach of classifying the timing of SM. In addition, we adjusted for potential confounders.

MATERIALS AND METHODS

Data and Subjects

A total sample of 1501 American boys and 1520 nonpregnant American girls aged 8 to 14 were included. Younger children were not included because data on SM were not collected; older adolescents were excluded because they could not be classified as early and average-late maturers using the proposed approach (see below). The subjects were separated into 2 age groups, children (8–11 years) and adolescents (12–14 years), but in the present study we used "children" for simplicity in some cases.

NHANES III, conducted in 2 phases between 1988 and 1994, was a cross-sectional representative sample of the US civilian noninstitutionalized population aged 2 months and older. NHANES III oversampled blacks, Mexican Americans, children under 5 years of age, and the elderly (≥60 years). Detailed descriptions of the sample design and operation of the survey are published elsewhere.[32] Standardized protocols were used for all interviews and examinations. Data on anthropometry, sociodemographic characteristics, diet (one 24-hour recall), and physical activity were collected for each individual. Maturation status for children aged 8 to 18 years was evaluated by physicians in the physical examination.

Outcome and Independent Variables

Anthropometry

Measures of weight, height, and skinfold thickness (triceps, subscapular, suprailiac, and thigh) were collected. We calculated BMI (= weight[kg]/height[m]^2) and the sum of skinfold thickness (= triceps + subscapular + suprailiac + thigh) for each individual.

Definitions of Overweight and Obesity

Because direct measurement of adipose tissue is not feasible in many cases, particularly in population-based research, simple anthropometric indices such as BMI are recommended to classify overweight in children and adults.[2,25,33–36] To define overweight and obesity, we used the 2000 Center for Disease Control and Prevention (CDC) growth charts (BMI cutoffs), ie, the 85th percentile for overweight and 95th percentile for obesity.[35]

Sexual Maturation Status

Data on Tanner stages (pubic hair stages for both sexes, breast stage for girls, and genitalia stages for boys, which were evaluated by physicians in the physical examination) were collected for children and adolescents aged over 8 years, and self-reported age at menarche was collected for girls. We chose to use breast stages (stage 1–5) for girls and genitalia stages (stage 1–5) for boys to classify children's SM status, because median ages at breast stage 2 and genitalia stage 3 are recommended by a World Health Organization Expert Committee as indicators of SM for international use.[25] For children and adolescents of the same age, those at a higher Tanner stage were more advanced in SM status.

Early Onset of Sexual Maturation

Subjects were grouped as "early maturers" if they reached a certain SM stage earlier than the median age for that stage in the population, and otherwise, as "the others" (average and late maturers). For example, a girl would be classified as an early maturer if she was at breast stage 2 and her chronological age was less than the median age for breast stage 2. Using the status quo method with probit analysis, we calculated the median age for each Tanner stage for girls and boys. The status quo method is recommended for calculating median ages of maturation events from cross-sectional data.[25,26] Only data on each individual's chronological age (in years rounded to 0.1 in our analysis) and SM status (eg, breast stage 2: yes or no) were necessary. Compared with retrospective methods based on self-reported menarcheal age, this method suffers from less recall errors. (Note more details about the probit analysis and the results are available from the author at request.) In addition, following the similar procedures, analyses were also conducted using pubic hair stages. We found a moderate agreement between pubic hair stages and the other 2 SM indicators (breast and genitalia stages) in classifying early and nonearly maturers (the agreement and κ was 77% and 0.48 for girls and, 74% and 0.33 for boys, respectively). This particularly was attributable to the fact that pubic hair stages are a less favorable indicator of SM than the other 2 indicators, which might have resulted in more misclassifications.[25]

Main Covariates

The following covariates were included in our analysis: 1) age; 2) race and ethnicity: based on self-reported race and ethnicity information, subjects were classified into 4 groups: non-Hispanic white, non-Hispanic black, American Mexican, and other. (Note that race and ethnicity is also likely an indicator of socioeconomic status [SES]); 3) SES: household income was used as an indicator of SES. A measure of family income relative to poverty line (ie, "poverty ratio") was provided by the CDC/National Center for Health Statistics, which allows for appropriate comparisons across regions and groups; 4) energy intake: Total energy intake calculated by the National Center for Health Statistics based on one 24-hour recall. We also examined dietary fat intake (as percentage of energy from fat) but chose not to include it in the final models, because it was not a significant regressor and did not improve model fit; 5) physical activity (answers to "Times per week exercise made you sweat?") and inactivity (answers to "Hours of TV watched yesterday"); and 6) urban versus rural residence. These covariates were tested and controlled for as potential confounders,

because studies show that they are risk factors for obesity,[2,37] and there is no evidence suggesting that they are the intermediates in the pathway between SM and obesity.

Data Analysis

We first examined the prevalence of overweight and obesity in American boys and girls stratified by their SM status (ie, early maturers and nonearly maturers). Student t tests were performed to test the differences between early and nonearly maturers. Then, with logistic regression we studied the associations between overweight, obesity, and SM (early maturers vs the others). Finally, using multiple linear regression analysis, we examined the association between SM, BMI, and skinfold thickness. All regression analyses were conducted for boys and girls separately and adjusted for age, race/ethnicity, family income, urban-rural residence, total energy intake, physical activity, and inactivity (television viewing time). Collinearity was tested by examining the variance inflation factor. No collinearity was detected, as none of the variance inflation factors was >10.[38] In general, the correlation coefficients between the independent variables were small (all <0.2). Furthermore, analyses adjusting for height were run, and results (not presented) were compared with the above results. In general, the 2 sets of findings were consistent, although discrepancies were observed in some cases. Height was not controlled for in the final models, because we suspected that SM affects obesity at least partly because it influences individuals' linear growth during childhood and adolescence. Data management and data analysis were performed with SAS Version 8.0 (SAS, Cary, NC) and Stata Version 7.0 (Stata Co, College Station, TX). We used Stata survey procedures that accounted for sampling weights to allow generalization of the results to the population of children and adolescents in the United States and to adjust standard errors for cluster sampling.

RESULTS

Characteristics of the Study Population and the Early and Nonearly Maturers

The main characteristics of the study population are shown in Table 1. Approximately two thirds of the subjects were aged 8 to 11 years (eg, 1002 of 1501 boys). Because of the oversampling of minority groups in NHANES III, approximately one third of our subjects were white, black, and Mexican American, respectively. Slightly more boys were overweight or obese than girls. Twenty-nine percent of boys were overweight or obese, and 12.6% were obese. Over a quarter of girls (26.5%) were overweight or obese, and 10.3% were obese.

Nearly one third (29%) of American children and adolescents were classified as early maturers based on the proposed approach. Non-Hispanic black boys and girls (38% vs 50%) matured earlier than non-Hispanic white (25% vs 26%) and Mexican American children and adolescents (25% vs 32%). Interestingly, boys of other races/ethnicities mature earlier (44%), whereas girls of other races/ethnicities (18%) matured later than all the other racial/ethnic groups. There was no age difference between early and nonearly maturing boys, mean (standard deviation) of age (years) was 11.2 (1.8) versus 11.2 (2.1), but early-maturing girls were older than nonearly maturers (P < .05): 11.6 (1.8) versus 11.1 (2.0). Compared with their average-late–maturing counterparts, on average, early-maturing boys were significantly (P < .05) taller (152.4 cm vs 148.2 cm), had smaller measures of triceps skinfold (10.7 mm vs 12.9 mm) and sum of skinfolds (40.8 mm vs 49.8 mm), and higher total energy intake (2580.3 kcal vs 2346.5 kcal); early maturing girls were heavier (weight: 50.4 kg vs 41.1 kg),

TABLE 1. Characteristics of American Boys and Girls Aged 8 to 14 Years, NHANES III (1988–1994)*

	Boys	Girls
Sample size		
All	1501	1520
Children (8–11 y)	1002	936
Adolescents (12–14 y)	499	584
Non-Hispanic white	380	392
Non-Hispanic black	539	525
Mexican American	518	537
Other	64	66
Characteristics		
Age (y, SE)	11.5 (0.1)	11.4 (0.1)
Children (8–11 y)	57.4%	59.5%
Adolescents (12–14 y)	42.6%	40.5%
Urban	46.7%	45.9%
Anthropometry (SE)		
Weight (kg)	44.9 (1.0)	43.9 (0.7)
Height (m)	149.4 (0.6)	147.8 (0.5)
BMI (kg/m²)	19.5 (0.3)	19.6 (0.2)
Triceps skinfold	12.3 (0.3)	15.4 (0.4)
Sum of skinfolds†	47.2 (1.2)	56.4 (1.0)
Overweight‡	29.1%	26.5%
Obesity§	12.6%	10.3%
Physical activity and diet (standard error)		
Physical activity times‖	6.8 (0.6)	6.6 (0.6)
TV hours¶	3.1 (0.1)	2.6 (0.1)
Total energy intake (kcal)#	2413.7 (54.9)	1930.8 (40.3)
Total energy intake (kJ)#	10089.3 (229.5)	8070.7 (168.5)
Fat intake (% energy)#	33.9 (0.4)	33.8 (0.4)

* National representative measures, and sampling weights were used.
† Sum of skinfolds = triceps skinfold + subscapular skinfold + suprailiac skinfold + thigh skinfold.
‡ Overweight, BMI ≥ sex–and age-specific 85th percentile.
§ Obesity, BMI ≥ sex–and age-specific 95th percentile.
‖ Answers to "times per week exercise made you sweat."
¶ Answers to "hours of TV watched yesterday."
# Based on a 24-hour recall.

and fatter (BMI [21.2 kg/m² vs 19.0 kg/m²], triceps skinfold [16.8 mm vs 14.8 mm], and sum of skinfolds [63.9 mm vs 53.4 mm]).

### Association Between Obesity and Early Sexual Maturation

The prevalence of obesity and overweight among boys and girls by SM status was presented in Figs 1 and 2. In general, compared with the average and late maturers, the prevalence of overweight and obesity was lower in early-maturing boys, but higher in early-maturing girls. The differences in the prevalence of obesity were more remarkable than those for overweight. The differences for children in the "other" race/ethnicity category were greater than those for other ethnic groups.

As shown in Table 2, the logistic regression analysis shows that early maturation is associated with a reduced risk for overweight and obesity for boys (OR and 95% confidence interval [CI]: 0.65 [0.44, 0.98] and 0.40 [0.20, 0.82], respectively), but with an increased risk for girls (odds ratio [OR] and 95% CI: 1.59 [1.05, 2.42] for overweight and 1.96 [1.11, 3.47] for obesity), controlling for other covariates.

Association Between Fatness (BMI and Skinfold Thickness) and Sexual Maturation

Using multiple linear regression analysis, we examined the associations between fatness and SM for

Fig 1. Prevalence (%) of overweight among early and average-late maturing American boys and girls, NHANES III data.
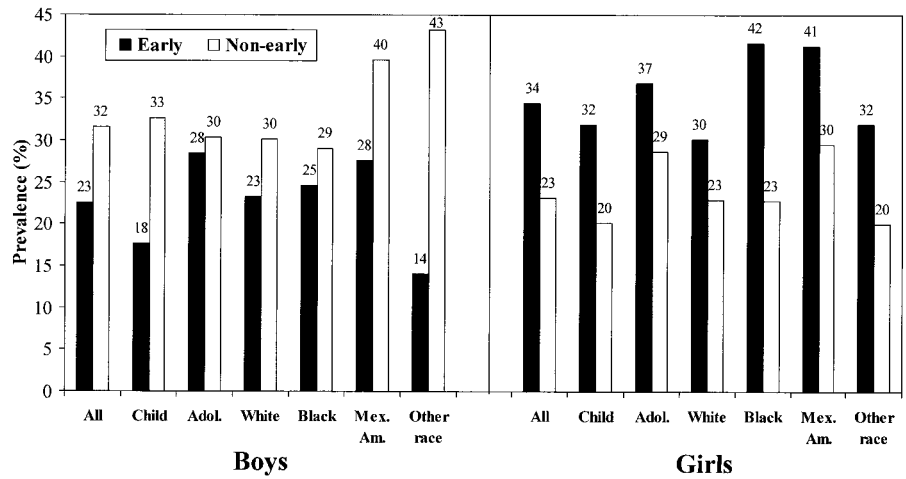
Overweight was defined as BMI>= 85th percentile, the 2000 CDC growth Curve. "Early maturers" were those who reached a specific Tanner stage earlier than the median age for that stage; and "non-early", average and late maturers. Children: 8-11 y; and adolescents: 12-14 y.

Fig 2. Prevalence (%) of obesity among early and average-late maturing American boys and girls, NHANES III data.

Obesity was defined as BMI>= 95th percentile, the 2000 CDC growth Curve. "Early maturers" were those who reached a specific Tanner stage earlier than the median age for that stage; and "non-early", average and late maturers. Children: 8-11 y; and adolescents: 12-14 y.
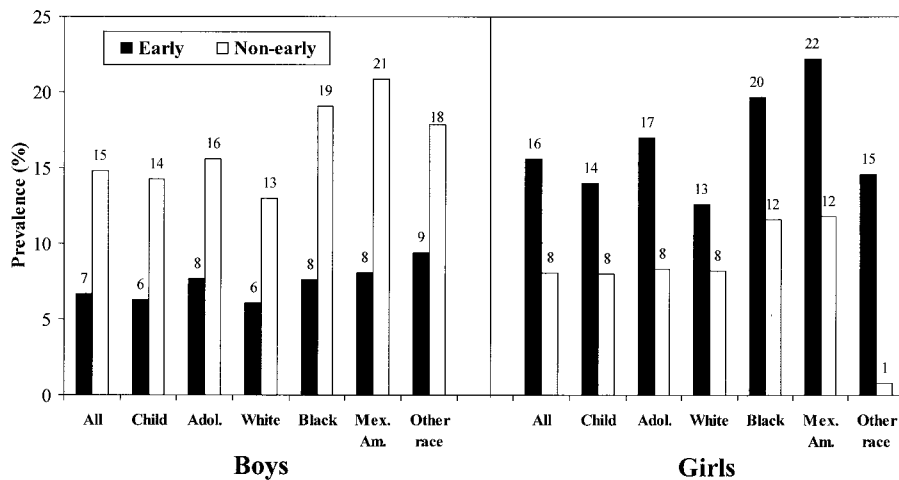
BMI, triceps skinfold, and the sum of skinfolds, respectively (details are not presented). In general, fatness was associated with Tanner stages in both boys and girls, although BMI was not associated specifically with genitalia stages in boys. Boys in advanced SM stages had smaller measures of skinfold thickness, whereas girls in advanced SM stages had greater measures of BMI and skinfold thickness compared with those being at SM stage 1. Age, ethnicity, and other covariates were adjusted for in the models.

As shown in Table 3, significant associations were observed between early SM and fatness for both boys and girls. Early-maturing boys had lower BMI and skinfold thickness measures than their counterparts; whereas early-maturing girls had greater measures of BMI and skinfold thickness. We also examined the influence of SM on boys' and girls' weight and height, which suggests an interesting gender differ-

ence. Early SM was related to increased height but not to increased body weight in boys, while it was associated with both increased height and weight in girls. This suggests that SM might have different biological influences on growth in weight and height in boys and girls, which may help explain the gender differences we observed for the associations between SM and fatness (BMI and skinfold thickness).

Interestingly, most of the significant ethnic differences in measures of fatness became insignificant or marginally significant after controlling for SM (Tanner stages and early maturation) and other covariates (Table 3). This indicates that differences in SM and SES are likely the major contributors of racial differences in fatness among American children and adolescents, although it is possible that genetic preposition might be a common risk factor for both obesity and early onset of SM.

TABLE 2. Logistic Regression Analysis: Association Between Early Sexual Maturation and Obesity*

	Boys		Girls	
	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval
Model 1: Overweight				
Early maturation	0.65	(0.44, 0.98)‡	1.59	(1.05, 2.42)‡
Race/ethnicity†				
Black	0.96	(0.69, 1.34)	1.22	(0.87, 1.70)
Mexican American	1.49	(1.07, 2.07)‡	1.40	(0.85, 2.31)
Other	1.41	(0.64, 3.09)	0.90	(0.42, 1.93)
Model 2: Obesity				
Early maturation	0.40	(0.20, 0.82)‡	1.96	(1.11, 3.47)‡
Race/ethnicity†				
Black	1.47	(0.92, 2.42)	1.55	(0.92, 2.59)
Mexican American	1.82	(1.03, 3.17)‡	1.80	(0.85, 3.83)
Other race	1.91	(0.85, 4.27)	0.36	(0.08, 1.61)

* Non-early maturers were the reference group. Age, family income, rural-urban residence, energy intake, physical activity, and inactivity (television time) were adjusted for. Sampling weights were used. Overweight, BMI ≥ 85th percentile; obesity, BMI ≥95th percentile.
† Whites were the reference group.
‡ $P < .05$.

TABLE 3. Multiple Linear Regression Analysis: Associations Between Early Maturation and Anthropometry Measures*

	BMI (kg/m²)		Triceps Skinfold (mm)		Sum of Skinfolds (mm)		Weight (kg)		Height (cm)	
	β	SE	β	SE	β	SE	β	SE	β	SE
Boys										
Early maturation	−0.61	0.35‖	−1.85	0.49§	−7.80	1.84§	0.45	0.98	2.55	0.62§
Age	0.88	0.17§	0.18	0.18	1.49	0.66§	5.72	0.54§	6.17	0.13§
Ethnicity†										
Black	−0.05	0.38	−0.65	0.40	−6.75	2.10§	−0.41	1.26	0.02	0.74
Mexican American	0.58	0.44	1.44	0.52§	3.63	2.15‖	−0.76	1.38	−2.70	0.78§
Other race	−1.04	0.50	−0.44	0.55	2.28	3.20	−1.66	1.63	−1.21	1.19
Girls										
Early maturation	1.50	0.41§	1.37	0.67‡	8.16	2.22‡	5.37	1.16§	3.48	0.68§
Age	0.83	0.07§	0.86	0.12§	3.24	0.58§	4.77	0.23§	5.12	0.18§
Ethnicity†										
Black	0.38	0.31	−0.43	0.59	−2.15	2.05	2.17	0.99§	2.06	0.65§
Mexican American	0.84	0.49‖	0.42	0.78	3.69	2.65	0.95	1.40	−1.36	0.58†
Other race	−0.81	0.46‖	−1.96	0.97‡	−4.55	3.45	−2.67	1.35†	−1.16	1.20

* Non-early maturers were the reference group. Family income, rural-urban residence, energy intake, physical activity, and inactivity (television time) were adjusted for. Sampling weights were used.
† Whites were the reference group.
‡ $P < .05$; § $P < .01$; ‖ Marginally significant, $P < .1$.

DISCUSSION

A large body of literature shows that SM is associated with body fatness in females, and early-maturing females are more likely to be obese during adolescence and into adulthood than among average- and late-maturing females.[4–17] Little is known, however, about males. To fill this major gap in the literature, we examined the association in boys using a US national representative sample. We found that although similarly to girls SM was closely associated with fatness (BMI and skinfold thickness) and obesity in boys, compared with nonearly maturers, early-maturing boys were less likely to be obese (OR: 0.4 [0.2, 0.8]), whereas early-maturing girls were twice as likely to be obese.

A thorough understanding of the relationship between SM and obesity is important for the development of appropriate approaches to consider SM in clinical settings and in epidemiologic research when assessing child and adolescent obesity. Our findings of a reverse association between SM and fatness in boys add new insights into this issue and provide additional evidence for the influence of SM on fatness. The current evidence linking fatness and maturational events (eg, menarche) does not confirm the direction of causation, which remains controversial. On balance, although the mechanisms of puberty remain poorly understood,[37] a growing literature seems to suggest a complex bidirectional causal relationship between early onset of puberty and obesity in females. According to Frisch's well-known "critical weight (fat) hypothesis" developed in the 1970s, a certain amount or percentage of body fat is needed for the onset of menarche, ie, heavier girls mature earlier.[7,8] It is hypothesized that subcutaneous fat tissue acts as a secondary hormonal gland and adipose tissue influences the synthesis and release of hormones (eg, estrogen), and thus promotes the onset of menarche.[7,8,20] On the other hand, the critical weight hypothesis has been questioned and criticized by many others with accumulating contradictory evidence.[5,9,18,19,21–23] Increasing evidence suggests that maturational timing affects body composition, at least, it has a greater long-term effect on fatness than the influence of fatness on the timing of SM.[9–12,17] Some longitudinal studies suggest that

earlier maturing girls have greater rates of increase in body weight and higher percentage of body fat and BMI than later maturing girls of the same age.[10,12,17] This is particularly attributable to hormonal changes (eg, estrogen levels) associated with SM, which promotes the development of adipose tissue. Studies, predominantly for females, show that numerous factors such as genetic predisposition, diet, nutritional status, socioeconomic conditions, exercise, general health and well-being, and climate acting in combination influence SM.[26,31,39,40] It is possible that some of these factors are the common causes of early onset of SM and obesity.

The gender difference we observed in the association between SM and obesity is likely attributable to the gender differences in biological development. The growth spurt in girls begins and ends earlier than in boys. During preadolescence, the proportions of adipose tissue and lean body mass in boys and girls are similar with body fat counts of ~15% and 19% muscle. In contrast, during adolescence, on average girls have relative greater increase in fat than fat-free mass, whereas boys gain more fat-free mass than fat mass. As a result, female adults have ~22% body fat compared with an average of 15% in males; boys gain twice as much lean body mass as girls.[31] We suspect that early onset of SM affects obesity partly because of its differential influence on growth in height and weight in boys and girls, whereas growth in height is a more important intermediate. For example, in boys, compared with average and late maturers, early maturers may utilize more energy and nutrients for growth in height while leaving less excess energy for the development of adipose tissue. We found that early-maturing boys were significantly taller, although their body weight was not significantly different from nonearly maturers. For girls, when height was adjusted, the association between early SM and obesity became insignificant in our study, although Adair and Gordon-Larsen[4] reported early SM (based on menarcheal age) remained a significant risk factor even when height was adjusted for.

Aside from the possible biological mechanisms, it is also of interest for future studies to examine how behavioral, social, and environmental factors may contribute to the gender differences. In wealthy societies such as the United States, social norms and expectations toward body weight are different for females and males; for example, thinness is viewed as attractive for females, whereas for males, bigness and muscularness are desirable.[37,41] This contributes to the gender differences in adolescents' body image, eating behavior, and exercise patterns as suggested by the US Youth Risk Behavior Surveys.[42,43] Studies from the development, psychology, and sociology literature suggest that pubertal development affects adolescents' emotional and social problems such as depression, anxiety, and risky behaviors, and there are gender differences.[44–46] It is possible that the interactions between biological maturation and social environmental factors play a role in the association between SM and obesity.

It has been of great interest to explain the ethnical disparities in obesity prevalence in the United States. Our findings that a large component of the ethnic differences (if not all) in fatness and obesity was explained by differences in SM provide some useful insights. For example, in girls, after controlling for SM stages, none of the ethnic differences in BMI, triceps skinfold, and sum of skinfolds remained statistically significant. Race/ethnicity was not a significant risk factor for overweight or obesity when early SM and other covariates such as diet and physical activity were adjusted for in the models. Our results are consistent with findings from the National Heart, Lung, and Blood Institute Growth and Health Study.[15] Studying a cohort of 2799 9- to 10-year-old American white and black girls, Morrison et al[15] found that after adjusting for maturation stage, the racial difference in BMI and the sum of skinfold thickness measurements became insignificant although on average black girls were fatter than white girls. A unique strength of the present study is that we were able to adjust for potential confounders such as diet and physical activity, which can help reduce potential bias.

Worth noting, we found that Mexican American boys remained at a higher risk of being obese than other race/ethnic groups even after controlling for SM and other covariates, which deserves additional investigation. The fact that Mexican American girls were not at an increased risk than other girls controlling for SM and other covariates indicates that genetic predisposition probably is not the full explanation for the racial/ethnic difference. Some risk factors related to ethnicity (eg, social and behavioral factors) may have not been measured adequately in the NHANES III data (eg, only one 24-hour dietary recall was collected); as a result, we could not control for them adequately. Furthermore, we tested the influence of height, another possible explanation for the ethnic difference in boys—BMI was associated with height during childhood and adolescence, and Mexican Americans were shorter than other ethnic groups. Interestingly, when height was adjusted for, the ethnic difference became greater (new OR, 95% CI: 2.53 [1.42, 4.51] for obesity). In summary, ours and others' findings show that racial differences in obesity are related to racial differences in SM.

This study has a few limitations. First, cross-sectional data were used, and as a result, causality cannot be proven. One should be cautious to make inference regarding causality based on the present study. Second, it will be desirable if more accurate assessment of the timing of SM were available. In the present study, early SM is defined as those who reached a certain Tanner stage earlier than the medina age for that stage. SM is a developmental process and consists of different stages. There are within individual variation (differential development from one stage to another) and between individual differences in the developmental process of SM.[26] The use of data collected at 1 time point (cross-sectional data) could misclassify some individuals' SM status. In addition, it might be possible that heavier girls could be more likely to be classified as being at higher breast stages. This potentially might inflate the asso-

ciation between early SM and obesity; however, the influence seems to be very small considering findings by others. The OR we observed and that reported by Adair and Gordon-Larsen[4] were consistent (they used age at menarche to classify early onset of SM). Finally, BMI percentiles were used to classify overweight and obesity following the CDC guidelines.[35] Although BMI is a good measure for overweight and obesity screening,[33–36] one needs to be aware of its limitations as an indirect measure of adiposity,[47] such as it cannot distinguish lean body mass and adipose tissue. We attempted to address this weakness by using additional measures of skinfold thickness to assess the association between SM and fatness.

CONCLUSION

The observed associations between sexual maturation and obesity presented here and by others may have important implications for the classification, management, and prevention of child and adolescent obesity. Currently, there is a tendency to uncritically apply BMI cutoffs for classifying child and adolescent overweight and obesity without fully recognizing their limitations and the potential misclassifications.[48–50] To our knowledge, none of the existing anthropometry references is able to account for children's sexual maturation status. Our previous work and other research have demonstrated that the adjustment for sexual maturation can make a considerable difference in the estimates of overweight prevalence.[13,24] Remarkable differences in maturation and growth patterns exist in different ethnic groups in the United States and in different populations worldwide.[26–28] Efforts should be made to develop appropriate guidelines and approaches to facilitate the consideration of maturational timing for assessing child and adolescent obesity. Additional prospective research is needed to study the causality between sexual maturation and obesity.

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SAMPLING METHODS

"There is a basic flaw [in many clinical surveys]: researchers collect what is called an 'opportunity sample.' The data are those most easily available. They do not have a truly representative sample of the entire distribution. . . the random sample is better than the opportunity sample [or other systematic methods] not because it guarantees correct answers, but because we can calculate a range of answers that will contain the correct answer with high probability."

Salzburg D. *The Lady Tasting Tea*. New York, NY: WH Freeman; 2001

Submitted by Student