

Research article

Open Access

The relation of menarcheal age to obesity in childhood and adulthood: the Bogalusa heart study

David S Freedman*¹, Laura Kettel Khan¹, Mary K Serdula¹,
William H Dietz¹, Sathanur R Srinivasan² and Gerald S Berenson²

Address: ¹Division of Nutrition and Physical Activity, Centers for Disease Control and Prevention, Atlanta, GA USA and ²Tulane Center for Cardiovascular Health, Tulane University School of Public Health and Tropical Medicine, New Orleans, LA USA

Email: David S Freedman* - DFreedman@cdc.gov; Laura Kettel Khan - ldk7@cdc.gov; Mary K Serdula - mks1@cdc.gov; William H Dietz - wcd4@cdc.gov; Sathanur R Srinivasan - ssriniv1@tulane.edu; Gerald S Berenson - Berenson@Tulane.edu

* Corresponding author

Published: 30 April 2003

Received: 23 January 2003

BMC Pediatrics 2003, 3:3

Accepted: 30 April 2003

This article is available from: <http://www.biomedcentral.com/1471-2431/3/3>

© 2003 Freedman et al; licensee BioMed Central Ltd. This is an Open Access article: verbatim copying and redistribution of this article are permitted in all media for any purpose, provided this notice is preserved along with the article's original URL.

Abstract

Background: Several studies have shown that girls who undergo menarche at a relatively young age tend to be more obese as adults. However, because childhood (pre-menarcheal) levels of weight and height are associated with an earlier menarche, the increased prevalence of adult obesity among early maturers may largely reflect the persistence of childhood obesity into adulthood.

Methods: We examined these interrelationships among 1179 girls (65% white, 35% black) who were examined as children (mean age, 9 y), adolescents, and adults (mean age, 26 y) in the Bogalusa Heart Study.

Results: Both white and black women who reported that they underwent menarche before age 12 y had, on average, higher adult levels of weight (+10 kg), body mass index (BMI, +4 kg/m²) and skinfold thicknesses (+6 mm) than did women who underwent menarche after age 13.5 y. However, relatively fat children tended to undergo menarche earlier than did thinner children, with each standard deviation increase in pre-menarcheal BMI increasing the odds of early menarche (<12 y) by approximately 2-fold. Stratified and regression analyses indicated that (1) adult obesity was more strongly associated with childhood obesity than with menarcheal age, and (2) about 60% to 75% of the apparent effect of menarcheal age was due to the influence of childhood obesity on both menarcheal age and adult obesity.

Conclusions: Although additional longitudinal studies are needed, it is likely that the importance of early menarche in adult obesity has been overestimated. Most of apparent influence of menarcheal age on adult obesity is attributable to the association of childhood obesity with both menarcheal age and adult obesity.

Background

Girls who experience a relatively early sexual maturation, typically assessed by age at menarche, tend to be more obese as adults [1–10]. For example, Garn et al [1] found that women (ages 20 to 35 y) who reported menarche before age 11 y were 2 to 3 kg/m² heavier than those who underwent menarche after 14 y. In addition to this association with adult levels of body mass index (BMI, kg/m²), menarcheal age is also inversely related to adult skinfold thicknesses [1–3,9]. Although there is at least one negative report [11], the lack of association between menarcheal age and adult obesity may be due to the difficulty in recalling an event that occurred several decades in the past [12].

Although the biological mechanisms underlying the inverse association between menarcheal age and adult obesity are uncertain, it has been suggested that early maturing girls may have a longer period of positive energy balance [1], or that various endocrine factors influence both the rate of sexual maturation and the accumulation of body fat [6]. However, it is also possible that the apparent influence of menarcheal age on adult obesity reflects the underlying importance of childhood obesity, with relatively fat children at increased risk for both early menarche [7,9,13–15] and adult obesity [7,16].

Disentangling these interrelationships requires information on menarcheal age, childhood obesity and adult obesity, and one study [7] found that adjustment for BMI at age 11 y reduced, but did not eliminate, the association between menarcheal age and adult obesity. A substantial proportion of girls in this study, however, experienced menarche close to age 11 y, and it is unclear if BMI levels at younger ages could also account for the apparent influence of menarcheal age on adult obesity. The present study explores the interrelationships between childhood levels of BMI, menarcheal age, and adult (ages 18 to 37 y) obesity in a biracial sample of 1179 women.

Methods

Sample

Bogalusa (Louisiana), a semi-rural community in Washington Parish (population, ~40,000), is 70 miles northeast of New Orleans. Seven cross-sectional studies of schoolchildren (ages, 5 to 17 y) were conducted in Ward 4 of Washington Parish between 1973–74 and 1992–94 [17]. In addition, four studies of adults (ages 18 to 37 y), who had been previously examined as children, were conducted between 1982 and 1996. Protocols were approved by appropriate institutional review boards, and informed consent was obtained from all participants. Because many subjects participated in multiple examinations, we could conduct various longitudinal analyses. A 6-year-old examined in 1976, for example, was eligible for re-examination

in studies conducted in 1978, 1981, 1984, 1987, 1991, and 1996 (age 26 y).

Of the 5- to 17-year-old girls who were examined in the Bogalusa Heart Study between 1973 and 1994, a total of 3041 girls (1) participated in a risk-factor examination before menarche, and (2) were age-eligible to be re-examined in adulthood. (A 7-year-old examined in 1988, for example, could not have been re-examined as an adult.) Of these girls, 1232 were re-examined in adulthood. We excluded 53 subjects from the analyses because (1) the reported menarcheal age was younger than the age at a previous examination, (2) the first report of menarcheal age was made after age 30 y, (3) menarcheal age was never reported, or (4) data on premenarcheal weight or height were missing.

The final sample size was 1179, with each girl being examined (on average) 5 times between the ages of 5 and 37 years. In most analyses, premenarcheal levels of height, BMI and triceps skinfold thickness (TSF) were based on data from the initial childhood examination (mean age, 8.8 y), and adult levels of the anthropometric dimensions were based on those at the final (mean age, 26 y) examination. Because errors in recalling age at menarche likely increase with the duration of time, menarcheal age was based on data provided at the first report of this event. There were various combinations of baseline and follow-up examinations in this cohort, but the largest numbers of girls were followed from 1973–74 to 1988–91 (n = 343) or from 1973–74 to 1995–96 (n = 313).

Anthropometry

The examination procedures used in the Bogalusa Heart Study have been described [18]. Weight was measured to the nearest 0.1 kg using a balance beam scale, and height was measured to the nearest 0.1 cm with a manual height board. BMI (kg/m²) was used as an index of relative weight. Because of the variability in levels of weight, height and BMI by age among children, national US data (1963 to 1994) were used to convert these values into sex- and age-specific Z-scores [19,20]. These Z-scores express childhood levels of weight, height and BMI in the current study relative to those of similarly aged children examined between 1963 and 1994.

The TSF was measured three times in succession with Lange skinfold calipers, and the mean value is included in the analyses. The subscapular skinfold thickness was not measured until 1978–1979 (the third examination of schoolchildren), and levels are shown only for adults. The ratio of the subscapular skinfold thickness to TSF is used as a measure of central fat distribution.

Menarcheal History

As previously described [15], information on menarcheal age was obtained by a registered nurse. Girls in the 3rd grade and above were asked whether they had ever had a menstrual period, and if necessary, the term 'menstrual period' was explained. Post-menarcheal girls were asked to identify the year of their first period, with the help of questions such as, "Do you remember what grade you were in when you started having periods?"

Because most subjects provided the year, but not the month, of menarche, we assumed that all girls experienced menarche at the midpoint (July 1) of the specified year. Menarcheal age was then calculated by dividing the number of days between birth and July 1 of the reported year by 365.25.

Statistical Analyses

Levels of various childhood and adult characteristics were contrasted between white ($n = 771$) and black ($n = 408$) women. Race-specific levels of weight, height, BMI, and skinfold thicknesses among adults and children were also examined within categories (early: <12 y, intermediate: 12 to 13.4 y, or late: ≥ 13.5 y) of menarcheal age. Spearman (rank) correlation coefficients and odds ratios were also used to summarize the relation of menarcheal age to both childhood and adult levels of weight, height, BMI, and skinfold thicknesses.

To assess whether childhood differences in the anthropometric dimensions could account for the association between menarcheal age and adult obesity, regression-estimated differences in adult levels of BMI and TSF between early (menarche <12 y) and late (≥ 13.5 y) maturers were compared in two models. The first regression model controlled for only age, while the second model further adjusted for childhood levels of BMI and TSF. We assumed that the estimated differences in adult levels of obesity across menarcheal age categories in the fully adjusted model represented the independent relation of menarcheal age to adult levels of BMI and TSF, whereas differences between the two models represented the effects of menarcheal age that were attributable to childhood obesity.

Smoothed levels of BMI by age, based on lowess [21], are also shown for women who experienced early, intermediate, or late menarche. These analyses were further stratified according to childhood BMI (Z-score ≤ 0 vs Z-score > 0).

Results

Mean levels of various characteristics are shown in Table 1. On average, girls participated in approximately five examinations, and the mean age at the initial examination

Table 1: Mean Levels of Various Characteristics in the Study Sample

	Whites	Blacks
N	771	408
Number of examinations	4.6 \pm 1*	5.0 \pm 1*
2–4 examinations	45%	31%
≥ 5 examinations	55%	69%
Initial examination		
Year	1975 \pm 3	1973 \pm 3
Age (y)	8.7 \pm 2	8.9 \pm 2
Weight (kg)	29.2 \pm 10*	30.6 \pm 11*
Weight-for-Age Z ^a	-0.2 \pm 1*	0 \pm 1*
Height (cm)	130 \pm 15*	133 \pm 15*
Height-for-Age Z ^a	-0.2 \pm 1**	0.1 \pm 1**
BMI (kg/m ²)	16.8 \pm 3	16.9 \pm 3
BMI-for Age Z ^a	-0.06 \pm 1	-0.05 \pm 1
Triceps skinfold thickness (mm)	14 \pm 5**	12 \pm 5**
Menarcheal age (y) ^b	12.9 \pm 1	12.8 \pm 1
Menarche before age 12 y ^b	25%	30%
Final Examination		
Age (y)	26 \pm 4	26 \pm 4
Weight (kg)	66.7 \pm 17**	73.5 \pm 22**
Height (cm)	163 \pm 6	163 \pm 7
BMI (kg/m ²)	25.1 \pm 6**	27.7 \pm 8**
Triceps skinfold thickness (mm)	24 \pm 10	25 \pm 12
Subscapular skinfold (mm)	21 \pm 11**	25 \pm 13**

^a Z-scores express levels relative to those among children in national studies conducted between 1963 and 1994 (see Methods); ^b Based on data from the first examination at which menarche was first reported. The mean age of girls at this examination was 16 y. H₀: Black vs. white difference equals 0 as assessed by a t-test: * $p < 0.05$; ** $p < 0.001$

was ~ 9 y. Childhood levels of weight and height at the initial examination were similar to those expected, with Z-scores close to 0, but blacks were slightly taller and heavier than were whites. These racial differences in both weight and height resulted in very similar BMI levels among white and black girls, but the mean TSF was thicker among white girls. The mean menarcheal ages of whites and blacks were similar (12.8 vs 12.9 y), but blacks tended to be more likely (30% vs 25%, $p = 0.10$) to undergo a relatively early (<12 y) menarche. At follow-up (mean age, 26 y), black women had higher mean levels of weight (+6.8 kg), BMI (+2.6 kg/m²), and subscapular skinfold thickness (+4 mm) than did white women, but there was no racial difference in TSF.

Menarcheal age was inversely related to adult levels of weight, BMI, and skinfold thicknesses among adults (Table 2). As compared with late maturers (menarcheal age >13.5 y), women who had a relatively early menarche (<12 y) weighed more (+8 to 11 kg), had a higher BMI (+3.7 to 4.2 kg/m²) and had thicker (+5 to 7 mm) skinfolds in adulthood ($p < 0.001$ for all differences). The magnitudes of the various correlation coefficients ($r = -$

Table 2: Relation of Menarcheal Age to Adult Levels of Various Characteristics

	Menarcheal Age (y)			Correlation with Menarcheal Age ^a
	< 12	12–13.4	≥ 13.5	
Whites				
N	194	364	213	
Weight (kg)	73.2 ^b	64.8	64.1	-0.21*
BMI (kg/m ²)	27.6	24.4	23.9	-0.24*
BMI ≥ 30 kg/m ² (%)	32%	16%	11%	
Triceps skinfold thickness (mm)	28	24	23	-0.21*
Subscapular Skinfold (mm)	25	20	20	-0.21*
Subscapular / Triceps	0.92	0.84	0.85	-0.09* (0.02) ^c
Height (cm)	163	163	164	0.05
Blacks				
N	121	174	113	
Weight (kg)	80.6	71.2	69.4	-0.21*
BMI (kg/m ²)	30.3	26.9	26.1	-0.23*
BMI ≥ 30 kg/m ² (%)	42%	26%	23%	
Triceps skinfold thickness (mm)	29	24	22	-0.22*
Subscapular Skinfold (mm)	28	24	22	-0.24*
Subscapular / Triceps	1.00	1.03	0.97	-0.07 (-0.03) ^c
Height (cm)	163	163	163	0.05

^a Age-adjusted Spearman correlation coefficients; ^b Mean levels have been adjusted for the difference in examination ages across the 3 groups using linear regression; ^c Correlations in parentheses have been adjusted for both age and adult BMI. H₀: Spearman correlation = 0; *p < 0.001

Table 3: Relation of Menarcheal Age to Childhood (Pre-Menarcheal) Levels of Various Characteristics

	Menarcheal Age (y)			Correlation with Menarcheal Age ^a	Odds Ratio (1 Z-Score change) ^b
	< 12	12–13.4	≥ 13.5		
Whites					
N	194	364	213		
BMI (kg/m ²)	17.8 ^c	16.7	16.1	-0.26*	
BMI-for-age Z	0.37	-0.10	-0.39	-0.26*	2.0* (1.6–2.5)
Weight (kg)	32.0	28.9	26.9	-0.31*	
Weight-for-age Z	0.32	-0.25	-0.60	-0.32*	2.2* (1.8–2.8)
Height (cm)	132	130	128	-0.26*	
Height-for-age Z	0.17	-0.28	-0.54	-0.27*	2.0* (1.6–2.5)
Triceps skinfold thickness (mm)	16	14	14	-0.20*	
Blacks					
N	121	174	113		
BMI (kg/m ²)	17.6	16.6	16.4	-0.23*	
BMI-for-age Z	0.34	-0.15	-0.29	-0.26*	2.1* (1.5–3.0)
Weight (kg)	33.1	30.0	29.0	-0.31*	
Weight-for-age Z	0.46	-0.10	-0.38	-0.30*	2.5* (1.8–3.6)
Height (cm)	135	132	130	-0.29*	
Height-for-age Z	0.51	0.06	-0.28	-0.27*	2.6* (1.8–3.7)
Triceps skinfold thickness (mm)	13	12	11	-0.17*	

^a Spearman correlation coefficients have been adjusted for examination age; ^b Odds ratios, calculated in logistic regression models that control for examination age, summarize the increased risk for early (<12 y) vs later (≥ 12 y) menarche associated with a Z-score difference of 1 unit. For example, the odds that a white girl with a BMI-for-age Z of +0.5 would experience menarche by age 12 y was 2.0-fold higher than for a girl with a Z-score of -0.5; ^c Mean levels have been adjusted for the difference in examination ages across the 3 groups using linear regression. H₀: Spearman correlation = 0 or odds ratio = 1; * p < 0.001

Table 4: Estimated Differences in Adult Levels of BMI and Triceps Skinfold Thickness according to both Menarcheal Age and Childhood BMI

Comparison	Whites (n = 771)		Blacks (n = 408)	
	Age Adjusted ^a	Fully Adjusted ^b	Age Adjusted ^a	Fully Adjusted ^b
Early vs late Menarche ^c				
Adult BMI (kg/m ²)	3.6**	1.4*	3.2*	0.8
Adult triceps skinfold thickness (mm)	4.2**	1.9*	4.8*	2.2
Highest vs. lowest fourth of childhood BMI ^d				
Adult BMI (kg/m ²)	8.6**	8.1**	12.1**	11.9**
Adult triceps skinfold thickness (mm)	9.8**	9.0**	13.4**	12.9**

^a Age adjusted models for early vs late menarche control for childhood and adult ages; ^b Fully adjusted models for early vs late menarche control for childhood levels of BMI and triceps skinfold thickness (using linear and second-order terms), as well as for childhood and adult ages; ^c <12 y vs ≥ 13.5 y; ^d The proportion of children in each fourth of the BMI distribution are fairly similar to the proportion of girls with a menarcheal age <12 y (27%) and ≥ 13.5 y (28%). Fully adjusted models for childhood BMI controls for childhood and adult ages, and for menarcheal age. H₀: As assessed in linear regression models, the estimated difference in adult BMI or triceps skinfold thickness is equal to 0 between women who experienced an early vs. late menarche, or who were relatively fat vs. thin in childhood. * p < 0.05; **p < 0.001

0.21 to -0.24) with menarcheal age were similar between black and white women, but the associations were not linear. Whereas women who underwent an early menarche had elevated mean levels of BMI, weight and skinfold thicknesses in adulthood, levels of these characteristics differed only slightly between women who experienced an intermediate (age, 12–13.4 y) or late (age ≥ 13.5 y) menarche. Early menarche was also associated with a higher subscapular/triceps skinfold thickness ratio among white women, but this was largely because of the higher BMI levels among women with a central distribution of body fat ($r = 0.37$). Menarcheal age was not significantly related to adult height, but among white women, early maturers were, on average, 1 cm shorter than were late maturers ($p = 0.08$).

Among both white and black girls, higher pre-menarcheal (mean age, 9 y) levels of BMI, weight, height, and TSF were associated with an earlier menarche (Table 3). Among white girls, for example, those who underwent menarche before age 12 y had higher childhood levels of BMI (+1.7 kg/m²), weight (+5.1 kg), height (+4 cm) and TSF (+2 mm) than did those who underwent a relatively late (≥ 13.5 y) menarche. Furthermore, menarcheal age was more strongly related to levels of these characteristics in childhood, with correlations ranging up to -0.32, than in adulthood (Table 2, $r = -0.21$ to -0.24). Logistic regression analyses (final column) indicated that a difference of 1 standard deviation in levels of weight, height, and BMI approximately doubled the odds (range, 2.0 to 2.6) that a girl would experience menarche before age 12 y. Additional analyses indicated that these associations were evident even among the youngest children, with BMI levels among 5- to 6-year-olds inversely associated ($r = -0.22$ (whites) and -0.30 (blacks)) with subsequent menarcheal age.

We then examined whether the inverse relation of menarcheal age to adult levels of BMI and TSF resulted from the earlier menarche of girls who were already overweight in childhood (Table 4). As estimated in regression models that adjusted only for examination age, girls who underwent menarche before age 12 y were, on average, 3.2 kg/m² (blacks) to 3.6 kg/m² (whites) heavier as adults than were girls who underwent menarche after 13.5 y. However, adjustment for pre-menarcheal differences in levels of BMI and TSF reduced these adult differences by 60%–75%, to 0.8 kg/m² (blacks) and 1.4 kg/m² (whites). (Adjustment for childhood height, which was also associated with an earlier menarche, did not alter the relation of menarcheal age to adult levels of BMI and TSF.) Controlling for childhood levels of BMI and TSF also substantially reduced the adult differences in TSF between early and late maturers. Adult levels of BMI and TSF were more strongly associated with childhood levels of these characteristics (Table 4, bottom), with differences of 8.6 kg/m² (whites) and 12.1 kg/m² (blacks) between the outer fourths of the BMI distribution. Furthermore, in contrast to the associations with menarcheal age, these adult differences in BMI and TSF were only slightly reduced (<10%) after adjustment for menarcheal age.

The joint effects of menarcheal age and childhood BMI levels are shown in Figure 1 for whites (top) and blacks (bottom). (BMI values from all examinations were used in this analysis, resulting in a total of 5621 values among 1179 women.) Smoothed levels of BMI by age are shown in the left panels for girls who experienced an early (<12 y), intermediate, or late (≥ 13.5 y) menarche, and the higher BMI levels of early maturers are evident at all ages. However, further stratification by childhood BMI (Z-score ≤ 0 vs Z-score > 0, right panels) greatly reduced the differences between early and late maturers, and emphasized

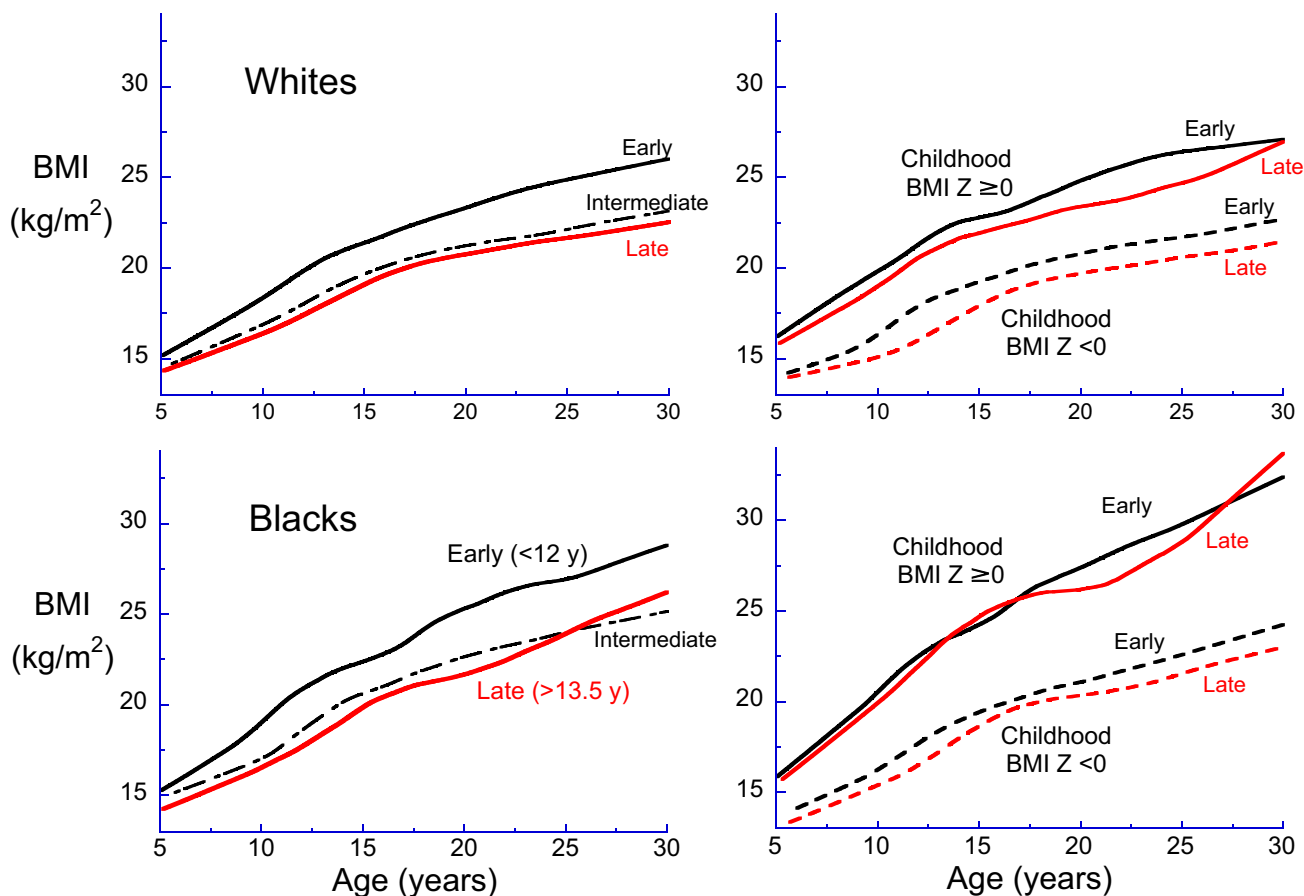


Figure 1
 Relation of menarcheal age and childhood obesity to smoothed (lowest) levels of BMI throughout life among white (top) and black (bottom) women. The left panels show BMI levels among women with an early (<12 y), intermediate (12 to 13.4 y), or late (≥ 13.5) menarcheal age. The right panels show BMI levels within categories of both childhood BMI (Z-score ≥ 0 vs. Z-score < 0) and menarcheal age (early vs late).

the greater importance of childhood BMI. For example, white women with an early menarche had an (overall) 3.5 kg/m² higher mean BMI level after age 18 y than those with late menarche, but as seen in the upper right panel, this difference was reduced to 2.1 kg/m² within the two groups of women categorized by childhood BMI. In contrast, among both early and late maturing white women, those who had a childhood BMI Z-score ≥ 0 were 4.7 to 4.8 kg/m² heavier in adulthood than women who were thinner in childhood.

Discussion

The recent secular increase in obesity among US adults [22], particularly among black women, emphasize the importance of identifying children who are at high risk for adult obesity. With only one exception [11], girls who un-

dergo a relatively early menarche have been found to be more obese in adulthood [1-10], and our results confirm that a relatively early menarche is associated with adult obesity among both white and black women. However, most (60% to 75%) of the apparent effect of menarcheal age is due to the faster maturation of girls who are relatively heavy for their age, and the importance of childhood obesity on the subsequent timing of menarche was evident even among 5- to 6-year-olds. In addition, we found that the inverse relation of menarcheal age to adult obesity was nonlinear, with differences in adult levels of BMI and skinfold thicknesses most evident between subjects with an early (<12 y) menarche and those who had either an intermediate or relatively late menarche.

Although it has been suggested that rapid sexual maturation may have long-term consequences for the development of obesity among women [6], our results indicate that it is more likely that childhood obesity influences both menarcheal age and adult obesity. These associations may be mediated by various interrelationships among hormones, sexual maturation, and body fat. For example, levels of leptin are increased among overweight children and adolescents [23,24], and this hormone is secreted by adipocytes. Other results indicate that leptin may play a role in the initiation of puberty [25], and each 1 ng/mL increase in serum leptin has been associated with a 1-month decrease in menarcheal age [24]. The apparent effect of early menarche on adult obesity may therefore result from the influence of childhood obesity on both the timing of menarche and the risk for adult obesity [16]. It should be realized, however, that although controlling for childhood BMI and TSF greatly reduced the inverse relation of menarcheal age to adult obesity, a relatively small, independent association remained. Various behavioral factors may also be important in this association, with an early puberty possibly resulting in changes in eating habits or physical activity [26].

Among women, black/white differences in BMI levels become apparent after age 12 y [27], suggesting that adolescence may be a critical period [28,29] for the development of obesity. It is possible that the more rapid sexual maturation of black girls [9,15,30,31] may, in part, account for the high prevalence of obesity among black women [22]. Although we observed only a small difference in the proportion of black (30%) and white (25%) who underwent menarche before age 12 y, most women in the current study experienced menarche before 1980. More recent data indicate that black girls in the US, on average, experience menarche ~6 months earlier than do white girls [9,15,30,31]. Furthermore, the mean menarcheal age of black girls in Bogalusa decreased by approximately 9 months between 1973 and 1992 [15]. A somewhat similar, but not statistically significant, trend was also reported in a recent study, with the median menarcheal age of black girls decreasing by 5.5 months between 1960–70 and 1988–94 [31]. These trends may, at least in part, be due to the influence of various programs in the US, such as the National School Lunch Program, aimed at improving the nutritional status of children.

Menarcheal age was also inversely related to adult BMI levels in the British Birth Cohort, with a mean difference of 4.1 kg/m² at age 33 y between women who underwent menarche before age 12 y (n = 159) or after age 15 y (n = 232) [7]. In agreement with our findings, Power et al. [7] found that adjustment for childhood (age 11 y) BMI levels 'substantially reduced', but did not eliminate, the apparent influence of early maturation on adult obesity. How-

ever, these investigators did not provide an estimate of the independent association between menarcheal age and adult obesity, and it is possible that BMI levels at age 11 y were influenced by the many changes that occur near the time of menarche [32]. We found that even among 5- to 6-year-olds, BMI levels are inversely associated with the subsequent timing of menarche.

In agreement with our findings, as well as those of a previous report from the Bogalusa Heart Study [15], other investigators have found childhood levels of obesity [9,33,34] and height [35,36] to be associated with an early menarche. The previously reported, positive association between childhood height and adult obesity [37] may therefore be, in part, due to the earlier menarche of relatively tall girls. Although several investigators have also found that an early menarche is associated with shorter adult stature [2,5,9,10,13], possibly because of the loss of several years of growth due to the early fusion of the epiphyses of long bones [5], most of the reported differences in adult height have been small (e.g., <2 cm). In the current study, we found a 1 cm difference in adult height across categories of menarcheal age among white girls (p = 0.08), but there was no association among black girls. Any association between menarcheal age and adult height is likely to be small.

Several limitations of the current study should be considered when interpreting our results. Despite the large sample size, only 1179 of the 3041 age-eligible children were reexamined as adults and included in the analyses. However, the sample appeared to be representative of the larger population, and childhood levels of BMI, weight, and height did not differ between the 1179 re-examined children and the other 1862 (3041 minus 1179) children. The agreement of our findings, concerning the interrelationships among childhood obesity, menarcheal age and adult obesity, with those of other investigators also indicates that our results are likely to be generalizable to other populations.

The most important limitation of the current study may be the use of self-reported menarcheal age, and the misclassification associated with this recall over several decades may explain the negative findings that have been reported [11]. Over shorter (<10 years) periods, however, correlations between the first report of menarcheal age (obtained close to the time of menarche) and a subsequent report have generally been high [38], with 60% of girls accurately recalling the month and year of menarche [39]. Among the 1014 girls in the current study who participated in more than one examination after menarche, 73% of the recalled ages (at the first and second reports) differed by one year or less, and only 5% differed by more than two years. (The mean interval between these two ex-

aminations was 5 years, but was more than 10 years for ~10% of the sample.) Although this reproducibility is somewhat lower than in other studies, a non-differential misclassification of menarcheal age would have resulted in an underestimation of the actual associations. In addition, it is possible that the information on menarcheal age obtained at the first examination following menarche (mean interval, 3 y) may be more accurate than subsequent recalls. Additional analyses indicated that both childhood and adult obesity tended to be more strongly associated with menarcheal age reported at the first examination than at the second examination following this event (e.g., $r = -0.22$ vs -0.19 with adult BMI).

Conclusions

Our findings indicate that much of the apparent influence of menarcheal age on adult obesity is, in reality, due to the influence of childhood obesity on both menarcheal age and adult obesity. However, there is still an independent association which, in conjunction with the increase in childhood obesity [40] and the recent secular decrease in the menarcheal age of black girls in the US [15,30,31], will further increase the prevalence of adult obesity. Additional longitudinal studies of childhood and adult obesity, as well as predictors of early menarche, are needed, but is likely that the prevention of childhood obesity will lower the incidence of obesity-related complications among adults.

Abbreviations

BMI, body mass index; TSF, triceps skinfold thickness

Competing interests

None declared.

Authors' contributions

DSF participated in the data analyses, manuscript preparation, and manuscript revision. LKK, MKS, and WHD critically reviewed the analyses and the manuscript, and provided suggestions for additional analyses and manuscript revision. SRS and GSB participated in the data collection, critically reviewed the manuscript, and provided suggestions for manuscript revision. All authors read and approved the final manuscript.

Acknowledgments

Supported by NIH grants HL-38844 (National Heart, Blood and Lung Institute) and AG-16592 (National Institute on Aging), by funds from the Centers for Disease Control and Prevention, and the Robert W. Woodruff Foundation.

References

- Garn SM, LaVelle M, Rosenberg KR and Hawthorne VM **Maturational timing as a factor in female fatness and obesity** *Am J Clin Nutr* 1986, **43**:879-883
- Sharma K, Talwar I and Sharma N **Age at menarche in relation to adult body size and physique** *Ann Hum Biol* 1988, **15**:431-434
- Wellens R, Malina RM, Roche AF, Chumlea WC, Guo S and Siervogel R **Body size and fatness in young adults in relation to age at menarche** *Am J Hum Biol* 1992, **4**:783-787
- St George IM, Williams S and Silva PA **Body size and the menarche: the Dunedin Study** *J Adolesc Health* 1994, **15**:573-576
- Helm P, Munster K and Schmidt L **Recalled menarche in relation to infertility and adult weight and height** *Acta Obstet Gynecol Scand* 1995, **74**:718-722
- van Lenthe FJ, Kemper CG and van Mechelen W **Rapid maturation in adolescence results in greater obesity in adulthood: the Amsterdam Growth and Health Study** *Am J Clin Nutr* 1996, **64**:18-24
- Power C, Lake JK and Cole TJ **Body mass index and height from childhood to adulthood in the 1958 British born cohort** *Am J Clin Nutr* 1997, **66**:1094-1101
- Laitinen J, Power C and Jarvelin MR **Family social class, maternal body mass index, childhood body mass index, and age at menarche as predictors of adult obesity** *Am J Clin Nutr* 2001, **74**:287-294
- Biro FM, McMahon RP and Striegel-Moore R **Impact of timing of pubertal maturation on growth in black and white female adolescents: The National Heart, Lung, and Blood Institute Growth and Health Study** *J Pediatr* 2001, **138**:636-643
- Okasha M, McCarron P, McEwen J and Smith GD **Age at menarche: secular trends and association with adult anthropometric measures** *Ann Hum Biol* 2001, **28**:68-78
- Frisancho AR and Housh CH **The relationship of maturity rate to body size and body proportions in children and adults** *Hum Biol* 1988, **60**:759-770
- Must A, Phillips SM and Naumova EN **Recall of early menstrual history and menarcheal body size: after 30 years, how well do women remember?** *Am J Epidemiol* 2002, **155**:672-679
- Jaruratanasirikul S, Mo-suwan L and Lebel L **Growth pattern and age at menarche of obese girls in a transitional society** *J Pediatr Endocrinol Metab* 1997, **10**:487-490
- Koprowski C, Ross RK, Mack WJ, Henderson BE and Bernstein L **Diet, body size and menarche in a multiethnic cohort** *Br J Cancer* 1999, **79**:1907-1911
- Freedman DS, Kettel Khan L, Serdula MK, Srinivasan SR and Berenson GS **The relation of age at menarche to race, time period, and anthropometric dimensions: the Bogalusa Heart Study** *Pediatrics* 2002, **110**:E43 [<http://www.pediatrics.org/cgi/reprint/110/4/e43.pdf>]
- Serdula MK, Ivery D, Coates RJ, Freedman DS, Williamson DF and Byers T **Do obese children become obese adults? A review of the literature** *Prev Med* 1993, **22**:167-177
- Freedman DS, Kettel-Khan L, Serdula MS, Srinivasan SR and Berenson GS **Secular trends in height among children over two decades: The Bogalusa Heart Study** *Arch Ped Adolescent Med* 2000, **154**:155-161
- Berenson GS and ed **Cardiovascular risk factors in children** New York: Oxford University Press 1980,
- Kuczumarski RJ, Ogden CL and Grummer-Strawn LM **CDC growth charts: United States** *Adv Data* 2000, **314**:1-27 [<http://www.cdc.gov/growthcharts/>]
- Ogden CL, Kuczumarski RJ and Flegal KM **Centers for Disease Control and Prevention 2000 growth charts for the United States: improvements to the 1977 National Center for Health Statistics version** *Pediatrics* 2002, **109**:45-60
- Cleveland WS **The Elements of Graphing Data** Monterey, CA: Wadsworth Advanced Books and Software 1985, 170-178
- Flegal KM, Carroll MD, Ogden CL and Johnson CL **Prevalence and trends in obesity among US adults, 1999-2000** *JAMA* 2002, **288**:1723-1727
- Carlsson B, Ankarberg C, Rosberg S, Norjavaara E, Albertsson-Wikland K and Carlsson LM **Serum leptin concentrations in relation to pubertal development** *Arch Dis Child* 1997, **77**:396-400
- Matkovic V, Ilich JZ and Skugor M **Leptin is inversely related to age at menarche in human females** *J Clin Endocrinol Metab* 1997, **82**:3239-3245
- Moschos S, Chan JL and Mantzoros CS **Leptin and reproduction: a review** *Fertil Steril* 2002, **77**:433-444
- Post GB and Kemper HC **Nutrient intake and biological maturation during adolescence. The Amsterdam growth and health longitudinal study** *Eur J Clin Nutr* 1993, **47**:400-408

27. Freedman DS, Kettel-Khan L, Srinivasan SR and Berenson GS **Black / white differences in overweight and obesity among girls: The Bogalusa Heart Study** *Prev Med* 2000, **30**:234-243
28. Dietz WH **Critical periods in childhood for the development of obesity** *Am J Clin Nutr* 1994, **59**:955-959
29. Kimm SY and Obarzanek E **Childhood obesity: a new pandemic of the new millennium** *Pediatrics* 2002, **110**:1003-1007
30. Herman-Giddens ME, Slora EJ and Wasserman RC **Secondary sexual characteristics and menses in young girls seen in office practice: a study from the Pediatric Research in Office Settings network** *Pediatrics* 1997, **99**:505-512
31. Chumlea WC, Schubert CM and Roche AF **Age at menarche and racial comparisons in US girls** *Pediatrics* 2003, **111**:110-113
32. Forbes GB **Body size and composition of perimenarchal girls** *Am J Dis Child* 1992, **146**:63-66
33. Frisch RE and Revelle R **Height and weight at menarche and a hypothesis of critical body weights and adolescent events** *Science* 1970, **169**:397-399
34. Kaplowitz PB, Slora EJ, Wasserman RC, Pedlow SE and Herman-Giddens ME **Earlier onset of puberty in girls: relation to increased body mass index and race** *Pediatrics* 2001, **108**:347-353
35. Ellison PT **Skeletal growth, fatness and menarcheal age: a comparison of two hypotheses** *Hum Biol* 1982, **54**:269-281
36. Moisan J, Meyer F and Gingras S **A nested case-control study of the correlates of early menarche** *Am J Epidemiol* 1990, **132**:953-961
37. Freedman DS, Kettel Khan L, Mei Z, Dietz WH, Srinivasan SR and Berenson GS **The relation of childhood height to obesity among adults: the Bogalusa Heart Study** *Pediatrics* 2002, **109**:e23 [<http://www.pediatrics.org/cgi/content/full/109/2/e23>]
38. Koprowski C, Coates RJ and Bernstein L **Ability of young women to recall past body size and age at menarche** *Obes Res* 2001, **9**:478-485
39. Koo MM and Rohan TE **Accuracy of short-term recall of age at menarche** *Ann Hum Biol* 1997, **24**:61-64
40. Ogden CL, Flegal KM, Carroll MD and Johnson CL **Prevalence and trends in overweight among US children and adolescents, 1999-2000** *JAMA* 2002, **288**:1728-32

Pre-publication history

The pre-publication history for this paper can be accessed here:

<http://www.biomedcentral.com/1471-2431/3/3/prepub>

Publish with **BioMed Central** and every scientist can read your work free of charge

"BioMed Central will be the most significant development for disseminating the results of biomedical research in our lifetime."

Sir Paul Nurse, Cancer Research UK

Your research papers will be:

- available free of charge to the entire biomedical community
- peer reviewed and published immediately upon acceptance
- cited in PubMed and archived on PubMed Central
- yours — you keep the copyright

Submit your manuscript here:
http://www.biomedcentral.com/info/publishing_adv.asp

