Published in final edited form as:

Nurs Res. 2009 ; 58(6): 382–390. doi:10.1097/NNR.0b013e3181b4b921.

Growth Differences by Age of Menarche in African American and White Girls

Pamela J. Salsberry, PhD, RN [Professor],

College of Nursing, The Ohio State University, Columbus, Ohio

Patricia B. Reagan, PhD [Professor], and

Department of Economics, Center for Human Resource Research, The Ohio State University, Columbus, Ohio

Kathleen Pajer, MD, MPH

Research Institute at Nationwide Children's Hospital, Associate Professor of Pediatrics and Epidemiology, Colleges of Medicine & Public Health, The Ohio State University, Columbus, Ohio

Abstract

Background—Because of the rapid increases in childhood obesity coupled with decreases in the median age of menarche, there is interest in how growth (body mass index [BMI] and height) in childhood may be associated with timing of menarche.

Objectives—Two research questions were addressed in this paper: (a) Within each race, at what ages were BMI and height differences evident among the early-, mid-, and late-onset groups? and (b) Within each timing group, at what ages were BMI and height differences evident between White and African American girls?

Methods—The Mother/Child files of the National Longitudinal Survey of Youth were used for this study. Menarcheal timing groups were identified using the 25th and 75th percentile of the age distribution for each race. Longitudinal statistical techniques were employed to estimate BMI and height as polynomial functions of age and age relative to menarche for African American and White girls.

Results—Significant differences in BMI by timing group were found. By age 3 years significant differences were found between early- and mid-onset African American girls, by age 5 years between mid- and late-onset African American girls, and by 6 years among the three timing groups of White girls. Significant height differences were evident by age 5 years when comparing early- to mid-onset and mid- to late-onset girls in both race groups. Comparing across race and within timing group, BMI and height differences were evident. African American girls were more likely than White girls to experience accelerated growth and earlier menarche.

Discussion—This is one of the few longitudinal studies of differences in growth by timing of menarche that includes data on girls younger than 5 years with large samples of both African American and White girls. Understanding when differences are first apparent is critical in establishing the critical period for prevention of these high-risk growth patterns.

Correspondence: Dr. Pamela J. Salsberry, Newton Hall, Rm. 315, 1585 Neil Ave., Columbus, Ohio 43210, Phone: 614-292-4907, Fax: 614-292-4948, salsberry.1@osu.edu.

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Keywords

age of menarche; race differences; body mass index (BMI); height

During the past 20 years, the United States has experienced rapid increases in childhood obesity (Ogden et al., 2006) as well as decreases in the median age of menarche among girls (Wattigney, Srinivasan, Chen, Greenlund, & Berenson, 1999). A reduction in age of menarche is a source of concern independent from rising childhood obesity because earlier age of menarche has been linked to a wide range of mental and physical health problems (De Stavola et al., 2004; Kaltiala-Heino, Kosunen, & Rimpela, 2003; Remsberg et al., 2005). These trends are found in all U.S. race and ethnic groups, but they are of particular concern for African American girls, because they have the lowest median age of menarche and the highest rate of childhood obesity. Fueled by concern over these trends, the association between childhood growth and onset of menarche have been examined in a number of studies.

Among the first studies of this association were those connected to the Frisch-Ravelle Hypothesis (Frisch & Revelle, 1970; Trussell, 1978) in which it was proposed that age of menarche was dependent on attainment of a critical body weight. It has been demonstrated since that an early age of menarche or pubertal initiation is associated positively with postmenarche body mass index (BMI) and associated negatively with postmenarche height (Lopez-Blanco, Izaguirre-Espinoza, Macias-Tomei, & Saab-Verardy, 1995; Must et al., 2005; Onland-Moret et al., 2005; Power, Lake, & Cole, 1997). There is general agreement that girls with a younger age of menarche experience accelerated growth and tend to be taller and heavier for some period in middle childhood prior to menarche when compared to later maturing girls of the same chronological age (Adair & Gordon-Larsen, 2001; Anderson, Dallal, & Must, 2003; Freedman et al., 2002; Wang, 2002).

There are several limitations to the current literature on timing of menarche and growth. First, many of the findings are based on cross-sectional samples such as the National Health and Nutrition Examination Survey (NHANES; Anderson et al., 2003; Sun et al., 2002; Wang, 2002). Second, in many of the longitudinal surveys, the collection growth measures did not begin until after girls were school age. Samples of older girls may increase the association spuriously between premenarcheal characteristics and age of menarche, because the early maturing girls already may be experiencing the growth spurt that occurs during adrenarche. The Newton study lacked multiple measures prior to menarche (Must et al., 2005); the 1958 British Birth Cohort's measures began at age 7 years (Power et al., 1997); the National Heart Lung and Blood study began at age 9 years (Biro et al., 2001); the average age of the first measurement in the Bogalusa Heart study was around 7.2 years (Freedman et al., 2002); and in the Add Health Survey, girls were surveyed first in the 7th grade (Adair & Gordon-Larsen, 2001). In these studies, it was documented consistently that there was greater adiposity both pre- and postmenarche, and shorter attained adult height in girls with earlier menarche. Also shown were significant differences in BMI trajectories beginning around 9 years of age for early-, mid-, and late-onset of menarche (Biro et al., 2001). In addition, several studies have found that early maturers have accelerated height velocity beginning at an earlier age than girls who are late maturers (Iuliano-Burns, Mirwald, & Bailey, 2001; Lopez-Blanco et al., 1995).

The longitudinal studies (Berkey, Gardner, Frazier, & Colditz, 2000; Demerath et al., 2004; Lee et al., 2007) that contain data on both age of menarche and height or weight measures in girls younger than 5 years were based on small samples that were not racially diverse. In a study using the Fels data on 211 White girls, BMI was centered on age relative to age of menarche and no BMI difference was found by menarcheal timing prior to menarche, but BMI differences were found by 4 to 6 years postmenarche (Demerath et al., 2004). The authors

concluded that weight differences were a consequence of timing of menarche, not a determinant.

In the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development, 291 White girls and 63 non-White girls were followed longitudinally from 36 months through the 6th grade. In a study based on these data, it was found that earlier onset of puberty was associated with higher BMI z-scores at 36 months, followed by more rapid increases in BMI z-scores during the period from 36 months to 1st grade (Lee et al., 2007). In a third study, based on 67 White girls born in Boston during the 1930s, girls with earlier menarche had greater BMI between the ages of 3 and 5 years (Berkey et al., 2000). Questions remain about the age at which differences in growth patterns associated with timing of menarche first become apparent. If girls with earlier menarche become taller and heavier at young ages than those with later menarche, then it is unlikely that obesity is a result of early menarche and more likely that obesity contributes to an earlier menarche or that a third factor influences both the timing of menarche and obesity development.

Finally, only a few longitudinal studies have had sufficient racial diversity to make comparisons between African American and White girls (Adair & Gordon-Larsen, 2001; Freedman et al., 2002; Onland-Moret et al., 2005). In those that do have sufficient diversity, it has been found that African American girls have an earlier median age of menarche than White girls, and that African American girls are heavier both pre- and postmenarche than White girls. However, none of these studies have data on girls younger than 5 years. Thus, there remains an open question about whether differences in timing of menarche and growth patterns in height and BMI are the same for African American and White girls.

The aim of this study was to examine the association between timing of menarche on growth patterns in height and BMI from early childhood through late adolescence in a racially diverse, longitudinal sample. The median ages at which African American and White girls were first observed were 30 months and 22 months, respectively. The onset of menarche was defined using race-specific cut points for early-, mid-, and late-onset menarche. Growth patterns were examined by chronological age and age relative to menarche. Two specific research questions were addressed: (a) Within each race, at what ages were BMI and height differences evident between the early-, mid-, and late-onset groups? and (b) Within each timing group, at what ages were BMI and height differences evident between White and African American girls?

The answer to question 1 is important in establishing the critical period for intervention, because once a child is established on a high BMI to early menarche pathway, preventions designed to alter this path become more difficult. The answer to question 2 is important for understanding the origins of the well-documented health disparities in health between African American and White women (Appel, Harrell, & Deng, 2002; Glanz, Croyle, Chollette, & Pinn, 2003) and for developing successful strategies to reduce these disparities.

Methods

Sample

The National Longitudinal Survey of Youth (NLSY79) began in 1979 with a representative sample of 2,477 White and 1,472 African American women born between 1957 and 1964 residing in the US in December 1978. Respondents were interviewed annually between 1979 and 1994 and biennially thereafter. In 1986, the scope of the survey was expanded to include the Children of the NLSY79 (CNLSY79), biennial interviews about the biological children of the NLSY79 female respondents. Beginning in 1994, children over the age of 14 years were interviewed directly. The 1986-2006 waves of the CNLSY79 surveys were used in this study.

In this study, the focus was on 3,349 non-Hispanic White and African American girls born before 1998 who were at least 8 years of age by the 2006 interview. Of these girls, 385 reported in the 2006 interview that they had not yet reached menarche. The eligible sample ($n = 2,964$) consisted of girls who were born before 1998, excluding girls who reported not having reached menarche in 2006. The sample size was reduced by missing data for the following reasons: (a) not interviewed in 2006 and no information indicating that the girl had reached menarche by a previous interview ($n = 128$); (b) girls (or mothers of girls) who could not recall their age of menarche in months ($n = 163$); or (c) missing data on height and weight at all interviews ($n = 6$). The final sample consisted of 2,667 girls (90% of the eligible sample): 1,219 African American girls and 1,448 White girls. The median age at which African American girls were first observed was 30 months, and the median age for White girls was 22 months.

Observations on height and weight at each interview conducted by the time of the girls' 20th birthday were used, for a total of 20,479 person-year observations. On average the African American girls were interviewed 7.3 times and the White girls were interviewed 7.9 times. There were 8,978 person-age observations on African American girls and 11,501 person-age observations on White girls. There was missing data on height and weight in 163 (< 0.8%) of the person-age observations.

Data Construction and Measures

Age of menarche—Mothers of girls between age 8 and 13 years were asked if menarche had occurred during each interview up to the interview in which their response was *yes*. Girls age 14 years and over were asked directly. If the girl or her mother responded *yes*, the girl then was asked the month and year which, coupled with the year and month of birth, allowed for the computation of the age of menarche in months.

There is no standard definition of early-, mid-, and late-onset of menarche, and a variety of definitions have been used (Adair & Gordon-Larsen, 2001; Biro et al., 2001; Freedman et al., 2002; Power et al., 1997). The methods used in this study follow those used in other key longitudinal surveys, thus allowing for comparisons of results (Biro et al., 2001; Demerath et al., 2004). Menarcheal timing groups were identified using the 25th and 75th percentile of the age distribution for each race. The age profiles in months are detailed in Table 1 for each of the menarcheal groups by race.

To provide further context for these internally generated cut points, the 2005-2006 NHANES data were examined to determine the consistency with the NLS results. Although age of menarche is reported in the NHANES data only in years, those data showed that 30% of African American girls reported age < 12 years, 50% reported age = 12 or 13 years, and 20% reported age $\geq$ 14 years; whereas 19% of White girls (excluding Mexican Americans) reported age < 12 years, 56% reported age = 12 or 13 years, and 25% reported age $\geq$ 14 years. These results were therefore consistent with the NLS findings.

Race—Race for the girls in the NLSY79 is based on the race of the mother, which was determined during the initial mother interview by interviewer observation and self-identification.

Age at interview—Age in months at date of interview was available for all of the girls.

Age in months relative to age of menarche—Age in months relative to age of menarche was created by subtracting the age in months at menarche from the age in months at the interview date. For example, a girl observed 12 months before menarche would have age relative to menarche of -12.

Height and weight—Mothers of girls under the age of 14 years were given the option to report their heights and weights or have the interviewer complete these measurements. Approximately three-fourths of the heights and weights were measured directly. Heights and weights were completed with children wearing light clothing and without shoes. Interviewers were trained to conduct these measurements by the National Opinion Research Center at the University of Chicago. Girls 14 years and over also were given the option of self-reporting; BMI scores were calculated using the Centers for Disease Control SAS program designed for this purpose. A major advantage of using this program is that it includes cut points for biologically implausible values for heights and weights by age and sex, thus providing a reliable mechanism for data cleaning (Kuczmarski et al., 2002).

Analysis

Longitudinal statistical techniques were used to estimate BMI and height as polynomial functions of age and age relative to menarche for each race-timing group. Likelihood ratio tests were used in conjunction with preliminary plots of the raw data to determine the degree of the polynomial in age for each growth model. In the case of height as a function of age relative to menarche, preliminary data analysis suggested that growth in height was linear before menarche and increased at a decreasing rate for the first few years after menarche until growth stopped. Therefore, height was specified as a linear function of age before menarche with a quadratic spline for age after menarche to capture the postmenarche tapering off of the growth rate. Wald tests were used to test for differences across the early-, mid-, and late-onset groups within each race and to test for differences across race within each timing group.

In longitudinal methods, successive error terms in the growth regressions for any one child or children of the same mother are not independent; thus, the structure of their variance-covariance matrix must be identified. Two competing longitudinal models were considered: the fixed coefficients model and the random coefficients (mixed) model. The fixed coefficients model is based on the assumption that the coefficients are the same across all individuals and errors are not independent. The errors also have an unstructured variance-covariance matrix which allows for the possibility that variances increase over time. The mixed model is based on the assumption that the errors are correlated only at the individual child level and uncorrelated across children. It is also assumed that the child-specific variance, while varying across children, is constant over time and that the random coefficients are drawn from a normal distribution with constant, estimable mean and variance. Both models are appropriate for unbalanced data such as the ones used in this study, in which children are measured at different ages. The two models were compared using the Akaike information criteria (AIC). All analyses were conducted by maximum likelihood using Stata 9.2 with controls for whether weight and height were measured.

The estimates were used to predict height and BMI by age and age relative to menarche for girls in each of the race-timing groups. The standard errors of these estimates were used to construct 95% confidence intervals around height-BMI for each age. These confidence intervals were used then to identify at which ages significant differences in predicted height and BMI occurred across race-timing groups. The BMI and height were imputed for children who were interviewed but had missing data, under the assumption that the data were missing at random using Stata's multiple imputation of chained equations procedure. The imputation model included age, indicators for race, and indicators for menarcheal timing.

Results

Model Selection

In all cases, the AICs for the mixed (random coefficient) models were lower than those of the fixed coefficient models. Furthermore, the results were not changed if imputed observations on missing BMI and height were included in the sample. Therefore, all results are reported based on estimates from the mixed model without using imputed values. Likelihood ratio tests indicated that BMI was a cubic function of both chronological age and age relative to menarche, whereas height was a quadratic function of age. The coefficient estimates for the mixed model of BMI and height as a function of chronological age are presented in Tables 2 and 3. All coefficients were significant at the .01 percent level.

To aid interpretation of the estimates, the predicted values (and 95% confidence intervals) of BMI and height at selected ages, 2-8 years and 20 years of age, are presented in Tables 4 and 5. The race-specific graphs of BMI as a function of chronological age are presented in Figures 1a and 1b. Because height differences are small relative to levels of heights, graphs of predicted heights are not reported. Complete results of all predicted values are available from the authors upon request.

Body Mass Index and Height Differences among Early-, Mid-, and Late-Onset Groups by Race

Wald tests indicated that there were significant differences by timing of menarche in BMI and height equations for both African American and White girls. Significant differences in BMI between early- and mid-onset African American girls were found at 3 years of age, while differences in BMI between mid- and late-onset African American girls were found by 5 years of age. These differences remained significant through age 20 years. By age 4 years, significant differences in height were found between early- and mid-onset African American girls, while height differences between mid- and late-onset girls were found by 5 years of age. However, by age 14 years, there was no longer a statistically significant difference in the heights of early- and mid-onset African American girls. By age 16 years, the significant height difference between mid- and late-onset African American girls had disappeared. By age 18 years there was no significant height difference among any groups of African American girls.

Significant differences in BMI between early- and mid-onset and mid- and late-onset White girls were found by age 6 years. The BMI differences persisted through age 20 years for the three groups of White girls. By age 5 years, there was a significant height difference between early- and mid-onset White girls, as well as between mid- and late-onset White girls. The height differences disappeared by age 13 years between early- and mid-onset White girls, while the difference between mid- and late-onset White girls disappeared by age 16 years. By age 20 years, there remained a significant difference in the height of early- and late-onset White girls.

Race Differences in Body Mass Index and Height by Timing of Menarche

Wald testing indicated that there were significant differences between the races in BMI and height curves for all timing groups. Among early-onset girls, African American girls had higher BMIs than White girls at each chronological age. By age 6 years, early-onset African American girls were taller than White girls, but the height difference was no longer significant by 13 years of age. Among mid-onset girls, African American girls had higher BMIs than White girls, beginning at age 7 years. These differences persisted through age 20 years. Race differences in height for mid-onset girls were found at age 7 years, with African American girls taller than White girls, but those differences were no longer significant by age 13 years. Among late-onset girls, African American girls had higher BMI from age 8 years onwards. At age 8 years, African American late-onset girls were taller than White girls, but the height differences were no longer significant by age 14 years. It should be noted that the predicted BMIs for mid-

onset African American girls were in the same range as those found for early-onset White girls from age 3 years onwards. Even late-onset African American girls had BMIs comparable to those of early-onset White girls from age 16 years onwards. By 20 years of age, African American girls in each of the timing groups were overweight (BMI ≥ 25), while only the early-onset White girls were overweight at age 20 years.

Evidence from Body Mass Index and Height as a Function of Age Relative to Menarche

The results from mixed-model estimates of BMI and height as a polynomial function of age relative to menarche are displayed graphically. The predicted BMIs by age relative to menarche are displayed in Figures 2a and 2b. They indicate that differences in BMI by timing of menarche are significant 8 to 10 years prior to menarche among African American girls. Thereafter, there are no significant differences in BMI relative to age of menarche by timing groups for African American girls. Among White girls, there are significant differences in BMI 9 to 10 years prior to menarche. Thereafter, there are no differences between mid- and late-onset White girls. However, late-onset White girls have significantly lower BMI than mid-onset White girls by 2 years after menarche.

Predicted height as a function of age relative to menarche are displayed in Figures 3a and 3b. Late-onset girls are taller than mid-onset girls, who are in turn taller than early-onset girls in the 10 years prior to menarche. In addition, during the 10 years prior to menarche, late-onset girls grow at a slower rate than mid-onset girls, who in turn grow at a slower rate than early-onset girls. White girls are slightly taller than African American girls in each of the menarche groups between 8 and 10 years prior to menarche, but African American girls in each group are growing faster than White girls during this period.

Discussion

The first research question was focused on within-race BMI and height differences among the early-, mid-, and late-onset groups. While it has been found previously that girls who mature early are taller and heavier in middle childhood (Herman-Giddens, 2006; Herman-Giddens, Kaplowitz & Wasserman, 2004), few researchers have been able to determine the age that differences become evident. The current results contribute to the literature because the ages in which these differences are first apparent were identified. Across the three timing groups, significant differences in BMI were found by age 3 years between early- and mid-onset African American girls, by age 5 years between mid- and late-onset African American girls, and by 6 years for the three timing groups of White girls. Significant height differences were evident by age 5 years when comparing early- to mid-onset and mid-onset to late-onset girls in both race groups. These results are new and suggest that the pathway through which the growth patterns and maturation differences originate must begin in early childhood.

The results provide further evidence of the link between childhood obesity and an earlier maturation. Obesity is thought to play a determining role in the age of menarche, as body fat may exert a permissive effect on pubertal development through leptin released from adipocytes (Roemmich & Rogol, 1999). Leptin may signal the hypothalamic centers controlling satiety; energy expenditure; and regulation of sex hormones, cortisol, and growth hormone. However, these results also raise the question as to whether there is a third factor operating to bring about both an increased childhood BMI and early sexual maturation. One alternative explanation is that girls exposed to chronic stressful environments may have chronic activation of the HPA axis, which could produce increased body fat, early adrenarche, and puberty (Chang, Tzeng, Cheng, & Chie, 2000; Cizza et al., 2001; Dorn & Rotenstein, 2004; Terasawa & Fernandez, 2001). Understanding the triggers for these growth patterns are critical and, as shown here, must be focused on the young child. Otherwise, causes of growth acceleration cannot be disentangled from the effects of growth acceleration.

Question two was focused on race differences within a timing group. Four notable differences were found when comparing these results across race. First, BMI and height differences by menarcheal timing were evident earlier in African American girls when compared to White girls. Second, the BMIs of early-onset African American girls were very high and there were no comparable values for White girls. Third, late-onset White girls had significantly lower BMIs than any other group of either African American or White girls. Finally, 75% of the African American girls had predicted BMI ranges that were greater than or comparable to the early-onset White girls. Fifty percent of African American girls attained menarche before 12 years of age, compared to 28% of White girls. Together, these results suggest that the majority of African American females were experiencing childhood growth and maturation patterns that were similar to patterns experienced by early-onset White girls.

Earlier menarche has been tied to higher risk for breast cancer, metabolic syndrome, depression, and cardiovascular diseases in adult women (De Stavola et al., 2004; Frontini, Srinivasan, & Berenson, 2003; Kaltiala-Heino et al., 2003; Remsberg et al., 2005). The findings are exciting, as they point to a possible beginning explanation for the significant differences in health experienced between adult African American and White women. It is now known that early menarche is likely to be associated with poor adult health, and from the current study it is known that at least 50% of the African American girls fall into the early menarche range for White girls; these facts together result in the conclusion that the differences seen in African American women's health must be understood through pathways that can explain growth acceleration and early maturation. This provides a promising new line of research for investigating health disparities in African American women.

Finally, growth measures by age relative to menarche has not been well-researched. In the Fels study (Demerath et al., 2004), no difference was found by timing of menarche in BMI prior to menarche for White girls, but differences were found postmenarche, leading to the conclusion that obesity was a consequence--not a determinant--of menarche. The current results were different and suggest that there were significant BMI differences premenarche across all timing groups in African American girls and between early- and mid- or late-onset White girls, but not postmenarche in these groups.

The most significant limitation of this study is the use of self- or mother-reported age of menarche. Given the 2-year interval between interviews, the reports are likely to contain measurement error (Dorn, Dahl, Woodward, & Biro, 2006; Dorn, 2006). In addition, menarche is itself a proxy for timing of a more complex temporal process involving adrenarche, thelarche, and pubarche. The use of this noisy measure of puberty to stratify girls into three groups biases the results toward the null finding of no differences between the menarche timing groups. Although the current measure of menarche is more reliable than retrospective reports by adult women, it is still less accurate than data collected more frequently, or data based on objective measures such as hormone levels and physical exams. Future research could benefit also from more objective measures of adiposity, including waist-to-hip ratios.

Conclusions and Implications

The current study demonstrates that higher BMI and height are antecedents, not consequences, of early menarche. Growth acceleration may be linked to maturational timing through a direct causal path, or early maturation and growth acceleration may both be the result of a very early common pathway. Growth curves and age of menarche differed between the two racial groups studied, with African American girls more likely to experience accelerated growth and earlier menarche. Since both high BMI and early menarche have been associated with health problems starting as early as adolescence, the findings raise concerns that racial disparities in health may be due to the pathway discovered in this study. The findings have important implications for clinical care and future research about somatic development and the timing of puberty.

In the young child, these results highlight the importance of careful assessment and tracking of growth measures (height, weight, BMI, and BMI percentile). Nurses involved in the care of infants and preschoolers may have a unique opportunity to influence the long-term health of girls by careful observation and identification of risky growth patterns during this period. Girls whose height acceleration begins before age 6 years may need more frequent assessments as well as targeted education of the parents regarding nutrition and activity. In the school-aged girl, identifying growth patterns, rather than simple cross-sectional measures, is important for targeted interventions. Nurses working in schools and primary care practices should think about patterns of growth as well as one-time measures of BMI and height percentiles. While these assessments ought to occur in all children, they may be most critical for African American girls. Slowing rapid growth and early maturation may be key to reducing health disparities between African American and White women.

Acknowledgments

Research supported by the National Institutes of Health, National Institute of Nursing Research (Salsberry, PI).

References

- Adair LS, Gordon-Larsen P. Maturation timing and overweight prevalence in US adolescent girls. *American Journal of Public Health* 2001;91(4):642–644. [PubMed: 11291382]
- Anderson SE, Dallal GE, Must A. Relative weight and race influence average age at menarche: Results from two nationally representative surveys of US girls studied 25 years apart. *Pediatrics* 2003;111(4 Pt 1):844–850. [PubMed: 12671122]
- Appel SJ, Harrell JS, Deng S. Racial and socioeconomic differences in risk factors for cardiovascular disease among Southern rural women. *Nursing Research* 2002;51(3):140–147. [PubMed: 12063412]
- Berkey CS, Gardner JD, Frazier AL, Colditz GA. Relation of childhood diet and body size to menarche and adolescent growth in girls. *American Journal of Epidemiology* 2000;152(5):446–452. [PubMed: 10981459]
- Biro FM, McMahon RP, Striegel-Moore R, Crawford PB, Obarzanek E, Morrison JA, et al. 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. *The Journal of Pediatrics* 2001;138(5):636–643. [PubMed: 11343036]
- Chang SH, Tzeng SJ, Cheng JY, Chie WC. Height and weight change across menarche of schoolgirls with early menarche. *Archives of Pediatrics & Adolescent Medicine* 2000;154(9):880–884. [PubMed: 10980790]
- Cizza G, Dorn LD, Lotsikas A, Sereika S, Rotenstein D, Chrousos GP. Circulating plasma leptin and IGF-1 levels in girls with premature adrenarche: Potential implications of a preliminary study. *Hormone and Metabolic Research* 2001;33(3):138–143. [PubMed: 11355746]
- De Stavola BL, dos Santos Silva I, McCormack V, Hardy RJ, Kuh DJ, Wadsworth ME. Childhood growth and breast cancer. *American Journal of Epidemiology* 2004;159(7):671–682. [PubMed: 15033645]
- Demerath EW, Li J, Sun SS, Chumlea WC, Remsberg KE, Czerwinski SA, et al. Fifty-year trends in serial body mass index during adolescence in girls: The Fels Longitudinal Study. *The American Journal of Clinical Nutrition* 2004;80(2):441–446. [PubMed: 15277168]
- Dorn LD. Measuring puberty. *The Journal of Adolescent Health* 2006;39(5):625–626. [PubMed: 17046496]
- Dorn LD, Dahl RE, Woodward HR, Biro F. Defining the boundaries of early adolescence: A user's guide to assessing pubertal status and pubertal timing in research with adolescents. *Applied Developmental Science* 2006;10(1):30–56.
- Dorn LD, Rotenstein D. Early puberty in girls: The case of premature adrenarche. *Women's Health Issues* 2004;14(6):177–183.
- Freedman DS, Khan LK, Serdula MK, Dietz WH, Srinivasan SR, Berenson GS. Relation of age at menarche to race, time period, and anthropometric dimensions: The Bogalusa Heart Study. *Pediatrics* 2002;110(4):e43. [PubMed: 12359816]

- Frisch RE, Revelle R. Height and weight at menarche and a hypothesis of critical body weights and adolescent events. *Science* 1970;169(943):397–399. [PubMed: 5450378]
- Frontini MG, Srinivasan SR, Berenson GS. Longitudinal changes in risk variables underlying metabolic syndrome X from childhood to young adulthood in female subjects with a history of early menarche: The Bogalusa Heart Study. *International Journal of Obesity and Related Metabolic Disorders* 2003;27(11):1398–1404. [PubMed: 14574352]
- Glanz K, Croyle RT, Chollette VY, Pinn VW. Cancer-related health disparities in women. *American Journal of Public Health* 2003;93(2):292–298. [PubMed: 12554589]
- Herman-Giddens ME. Recent data on pubertal milestones in United States children: The secular trend toward earlier development. *International Journal of Andrology* 2006;29(1):241–246. [PubMed: 16466545]
- Herman-Giddens ME, Kaplowitz PB, Wasserman R. Navigating the recent articles on girls' puberty in Pediatrics: What do we know and where do we go from here? *Pediatrics* 2004;113(4):911–917. [PubMed: 15060243]
- Iuliano-Burns S, Mirwald RL, Bailey DA. Timing and magnitude of peak height velocity and peak tissue velocities for early, average, and late maturing boys and girls. *American Journal of Human Biology* 2001;13(1):1–8. [PubMed: 11466961]
- Kaltiala-Heino R, Kosunen E, Rimpela M. Pubertal timing, sexual behaviour and self-reported depression in middle adolescence. *Journal of Adolescence* 2003;26(5):531–545. [PubMed: 12972267]
- Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC Growth Charts for the United States: Methods and development. *Vital Health Statistics* 2002;11(246):1–190.
- Lee JM, Appugliese D, Kaciroti N, Corwyn RF, Bradley RH, Lumeng JC. Weight status in young girls and the onset of puberty. *Pediatrics* 2007;119(3):e624–630. [PubMed: 17332182]
- Lopez-Blanco M, Izaguirre-Espinoza I, Macias-Tomei C, Saab-Verardy L. Growth in stature in early, average, and late maturing children of the Caracas mixed-longitudinal study. *American Journal of Human Biology* 1995;7(4):517–527.
- Must A, Naumova EN, Phillips SM, Blum M, Dawson-Hughes B, Rand WM. Childhood overweight and maturational timing in the development of adult overweight and fatness: the Newton Girls Study and its follow-up. *Pediatrics* 2005;116(3):620–627. [PubMed: 16099850]
- Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999–2004. *JAMA* 2006;295(13):1549–1555. [PubMed: 16595758]
- Onland-Moret NC, Peeters PH, van Gils CH, Clavel-Chapelon F, Key T, Tjønneland A, et al. Age at menarche in relation to adult height: the EPIC study. *American Journal of Epidemiology* 2005;162(7):623–632. [PubMed: 16107566]
- Power C, Lake JK, Cole TJ. Body mass index and height from childhood to adulthood in the 1958 British born cohort. *American Journal of Clinical Nutrition* 1997;66(5):1094–1101. [PubMed: 9356525]
- Remsberg KE, Demerath EW, Schubert CM, Chumlea WC, Sun SS, Siervogel RM. Early menarche and the development of cardiovascular disease risk factors in adolescent girls: the FELS Longitudinal Study. *Journal of Clinical Endocrinology and Metabolism* 2005;90(5):2718–2724. [PubMed: 15728207]
- Roemmich JN, Rogol AD. Hormonal changes during puberty and their relationship to fat distribution. *American Journal of Human Biology* 1999;11(2):209–224. [PubMed: 11533945]
- Sun SS, Schubert CM, Chumlea WC, Roche AF, Kulin HE, Lee PA, et al. National estimates of the timing of sexual maturation and racial differences among U.S. children. *Pediatrics* 2002;110(5):911–919. [PubMed: 12415029]
- Terasawa E, Fernandez DL. Neurobiological mechanisms of the onset of puberty in primates. *Endocrine Review* 2001;22(1):111–151.
- Trussell J. Menarche and fatness: reexamination of the critical body composition hypothesis. *Science* 1978;200(4349):1506–1513. [PubMed: 663636]
- Wang Y. Is obesity associated with early sexual maturation? A comparison of the association in American boys versus girls. *Pediatrics* 2002;110(5):903–910. [PubMed: 12415028]
- Wattigney WA, Srinivasan SR, Chen W, Greenlund KJ, Berenson GS. Secular trend of earlier onset of menarche with increasing obesity in black and white girls: the Bogalusa Heart Study. *Ethnicity & Disease* 1999;9(2):181–189. [PubMed: 10421080]

Figure 1.

a. Body Mass Index by Age in Years and Menarche Timing, African American

b. Body Mass Index by Age in Years and Menarche Timing, White

Figure 2.

- a. Body Mass Index Relative to Menarche, African American
 b. Body Mass Index Relative to Menarche, White

Figure 3.

- a. Height Relative to Age of Menarche, African American
- b. Height Relative to Age of Menarche, White

Table 1
Age Profiles in Months for Each Menarcheal Group, by Race

	White <i>n</i> = 2,477	African American <i>n</i> = 1,472
	<u>25th Percentile (Early-Onset)</u>	
Upper-bound	<141	<133
Mean age	131	123
Median age	133	123
	<u>25th to 75th Range (Mid-Onset)</u>	
Range	141-157	133-152
Mean age	149	143
Median age	149	144
	<u>75th Percentile (Late-Onset)</u>	
Upper-bound	>157	>152
Mean age	167	162
Median age	164	159

Table 2
Random Coefficient Estimates: Body Mass Index by Chronological Age

	Early	Middle	Late
White*age	-1.16	-1.38	-1.30
White*age-squared	0.18	0.19	0.16
White*age-cubed	-0.01	-0.01	0.01
African American*age	-1.40	-1.58	-1.70
African American*age-squared	0.22	0.23	0.22
African American*age-cubed	-0.01	-0.01	-0.01
African American	1.32	0.60	0.93
Constant	18.52	18.85	18.92
Standard Deviation (age)	0.34	0.31	0.30
Standard Deviation (constant)	2.03	1.99	1.78
Correlation (age, constant)	-0.51	-0.40	-0.47

Notes. Regression includes controls for whether height and weight were measured. All coefficients were significant at the .01 level

Table 3
Random Coefficient Estimates: Height in Inches

	Early	Middle	Late
White*age	0.38	0.36	0.33
White*age-squared	−0.00085	−0.00076	0.00
African American*age	0.40	0.37	0.35
African American*age-squared	−0.00097	−0.00084	0.00
African American	−0.39	−0.47	−0.75
Constant	24.04	24.20	24.78
Standard Deviation (age)	0.01	0.01	0.01
Standard Deviation (constant)	1.66	1.36	1.46
Correlation (age, constant)	−0.25	0.33	0.13

Notes. Regression includes controls for whether height was measured. All coefficients were significant at the .01 level.

Table 4
Predicted Body Mass Index as a Function of Chronological Age

Age (in years)	African American			White		
	Early	Middle	Late	Early	Middle	Late
2	17.4 (17.0,17.7)	16.7 (16.5,17.0)	16.6 (16.3,16.8)	16.3 (16.0,16.6)	16.3 (16.1,16.5)	16.2 (16.0,16.5)
3	16.9 (16.6,17.2)	16.1 (15.9,16.4)	15.9 (15.6,16.1)	16.0 (15.7,16.2)	15.8 (15.6,16.0)	15.7 (15.5,15.9)
4	16.8 (16.5,17.1)	15.9 (15.7,16.1)	15.6 (15.3,15.8)	15.9 (15.7,16.2)	15.6 (15.4,15.8)	15.4 (15.2,15.6)
5	16.9 (16.6,17.2)	16.0 (15.8,16.2)	15.5 (15.3,15.7)	16.1 (15.8,16.3)	15.6 (15.5,15.8)	15.3 (15.0,15.5)
6	17.4 (17.1,17.6)	16.3 (16.1,16.5)	15.7 (15.4,15.9)	16.4 (16.2,16.7)	15.9 (15.7,16.1)	15.3 (15.1,15.5)
7	18.0 (17.7,18.3)	16.8 (16.6,17.1)	16.1 (15.8,16.3)	17.0 (16.7,17.3)	16.3 (16.1,16.5)	15.6 (15.3,15.8)
8	18.8 (18.5,19.1)	17.6 (17.3,17.8)	16.7 (16.4,16.9)	17.7 (17.4,18.0)	16.9 (16.7,17.1)	15.9 (15.7,16.2)
20	28.1 (27.3,29.0)	26.0 (25.4,26.5)	25.1 (24.4,25.8)	25.6 (24.8,26.4)	23.8 (23.2,24.3)	21.9 (21.3,22.6)

Table 5
Predicted Height (in inches) as a Function of Chronological Age in Years

Age (in years)	African American			White		
	Early	Middle	Late	Early	Middle	Late
2	32.6 (32.3,32.9)	32.3 (32.2,32.5)	32.3 (32.1,32.6)	32.5 (32.3,32.7)	32.4 (32.3,32.6)	32.6 (32.4,32.8)
3	36.7 (36.4,36.9)	36.2 (36.1,36.4)	36.0 (35.8,36.3)	36.4 (36.2,36.6)	36.2 (36.1,36.3)	36.1 (35.9,36.3)
4	40.5 (40.3,40.7)	39.9 (39.7,40.0)	39.5 (39.3,39.7)	40.1 (39.9,40.3)	39.7 (39.6,39.9)	39.4 (39.2,39.6)
5	44.1 (43.8,44.3)	43.3 (43.1,43.4)	42.8 (42.6,43.0)	43.5 (43.3,43.7)	43.0 (42.9,43.2)	42.5 (42.3,42.7)
6	47.3 (47.1,47.6)	46.4 (46.3,46.6)	45.8 (45.6,46.0)	46.7 (46.5,46.9)	46.1 (46.0,46.3)	45.4 (45.3,45.6)
7	50.3 (50.1,50.5)	49.4 (49.2,49.5)	48.6 (48.4,48.8)	49.6 (49.4,49.8)	49.0 (48.9,49.1)	48.2 (48.0,48.4)
8	53.0 (52.8,53.3)	52.1 (51.9,52.2)	51.2 (51.0,51.5)	52.3 (52.1,52.5)	51.7 (51.5,51.8)	50.7 (50.5,50.9)
20	65.0 (64.6,65.3)	65.4 (65.1,65.7)	65.5 (65.1,65.9)	65.1 (64.9,65.4)	65.6 (65.4,65.8)	65.8 (65.5,66.1)