

BMI and Height Differences by age of Menarche in a U.S longitudinal sample of  
African-American and White Girls.

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1 Background: Because of the rapid increases in childhood obesity coupled with decreases in the  
2 median age of menarche there is interest in how growth (BMI & height) in childhood may be  
3 associated with timing of menarche.

4 Objectives: Two research questions were addressed in this paper. (1) At what ages were growth  
5 differences evident in early, mid, and late onset menarche groups? (2) Were the associations  
6 between growth and menarcheal timing similar for white and African-American girls?

7 Method: The Mother/Child files of the NLSY79 were used for this study. Menarcheal timing  
8 groups were identified using the 25<sup>th</sup> and 75<sup>th</sup> percentile of the age distribution for each race.  
9 Longitudinal statistical techniques were employed to estimate BMI and height as polynomial  
10 functions of age and age relative to menarche for African-American and white girls.

11 Results: Significant differences in BMI among African-American girls were found by 3 years  
12 between early and mid onset girls, and by 4 years between mid and late onset girls. Among white  
13 girls BMI differences were evident by 6 years between early and mid onset girls, and by 6 years  
14 between mid to late onset girls. Significant height differences were evident by 5 years when  
15 comparing early to mid onset and mid onset to late onset girls in both race groups. These results  
16 suggest that the pathway through which these growth patterns and maturation differences  
17 originate must begin in early childhood. These results also support recent research that links  
18 childhood obesity to an earlier maturation.

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

23 Key words: Age of menarche, race differences, BMI, height

24

## 1 Introduction

2           During the past twenty years, the U.S. has experienced rapid increases in childhood  
3 obesity (Ogden, et al., 2006) as well as decreases in the median age of menarche among girls  
4 (Wattigney, et al., 1999). Reductions in age of menarche is a source of concern independent from  
5 rising childhood obesity because earlier age of menarche has been linked to a wide range of  
6 mental and physical health problems (De Stavola, et al., 2004; Kaltiala-Heino, Kosunen, &  
7 Rimpela, 2003; Remsberg, et al., 2005). These trends are found in all U.S. race and ethnic  
8 groups but they are of particular concern for African-American girls because they have the  
9 lowest median age of menarche and the highest rate of childhood obesity. Fueled by concern  
10 over these trends, a number of studies have examined the association between childhood growth  
11 and onset of menarche. Among the first studies were those associated with the Frisch-Ravelle  
12 Hypothesis (Frisch & Revelle, 1970; Trussell, 1978) which proposed that age of menarche was  
13 dependent on attainment of a critical body weight. Many studies have since demonstrated that an  
14 early age of menarche or pubertal initiation is positively associated with post-menarche BMI and  
15 negatively associated with post-menarche height (Lopez-Blanco, Izaguirre-Espinoza, Macias-  
16 Tomei, & Saab-Verardy, 1995; Must, et al., 2005; Onland-Moret, et al., 2005; Power, Lake, &  
17 Cole, 1997). There is general agreement that girls with a younger age of menarche experience  
18 accelerated growth and tend to be taller and heavier for some period in middle childhood prior to  
19 menarche when compared to later maturing girls of the same chronological age (Adair &  
20 Gordon-Larsen, 2001; Anderson, Dallal, & Must, 2003; Freedman, et al., 2003; Wang, 2002).

21           There are several limitations to the current literature on timing of menarche and growth.  
22 First, many of the findings are based on cross sectional samples such as the NHANES  
23 (Anderson, et al., 2003; Sun, et al., 2002; Wang, 2002). Second, many of the longitudinal

1 surveys did not begin collecting growth measures until after girls were school age. Samples of  
2 older girls may spuriously increase the association between premenarcheal characteristics and  
3 age of menarche because the early maturing girls may already be experiencing the growth spurt  
4 that occurs during adrenarche. The Newton study lacked multiple measures prior to menarche  
5 (Must, et al., 2005); the 1958 British Birth Cohort's measures began at age 7 years (Power, et al.,  
6 1997); the National Heart Lung and Blood study began at age 9 years (Biro, et al., 2001); the  
7 average age of the first measurement in the Bogalusa Heart study was around 7.2 years  
8 (Freedman, et al., 2003); and the Add Health Survey first surveyed girls in the 7<sup>th</sup> grade (Adair &  
9 Gordon-Larsen, 2001). These studies have consistently documented greater adiposity both pre  
10 and post menarche and shorter attained adult height in girls with earlier menarche. They also  
11 show significant differences in body mass index (BMI) trajectories beginning around 9 years of  
12 age for early, mid, and late onset of menarche (Biro, et al., 2001). In addition, several studies  
13 have found that early maturers have accelerated height velocity beginning at an earlier age than  
14 girls who are late maturers (Iuliano-Burns, Mirwald, & Bailey, 2001; Lopez-Blanco, et al.,  
15 1995).

16         The longitudinal studies (Berkey, Gardner, Frazier, & Colditz, 2000; Demerath, et al.,  
17 2004; Lee, et al., 2007) that contain data on both age of menarche and height and/or weight  
18 measures in girls younger than 5 years were based on small samples that were not racially  
19 diverse. A study using the FELS data on 211 white girls centered BMI on age relative to age of  
20 menarche and found no BMI difference by menarcheal timing prior to menarche, but found BMI  
21 differences by 4 to 6 years post menarche (Demerath, et al., 2004). The authors concluded that  
22 weight differences were a *consequence* of timing of menarche, not a determinant. The National  
23 Institute of Child Health and Human Development Study of Early Child Care and Youth

1 Development followed 291 white girls and 63 non-white girls longitudinally from 36 months  
2 through the 6<sup>th</sup> grade. A study based on these data found that earlier onset of puberty was  
3 associated with higher BMIz scores at 36 months and followed by more rapid increases in BMIz  
4 during the period from 36 months to first grade (Lee, et al., 2007). A third study, based on 67  
5 white girls born in Boston during the 1930's, found that girls with earlier menarche had greater  
6 BMI between the ages of 3 and 5 years (Berkey, et al., 2000). Questions remain about the age at  
7 which differences in growth patterns associated with timing of menarche first become apparent.  
8 If girls with earlier menarche become taller and heavier than those with later menarche at young  
9 ages then it is unlikely that obesity is a result of early menarche and more likely that obesity  
10 contributes to an earlier menarche or that a third factor influences both the timing of menarche  
11 and obesity development.

12 Finally, only a few longitudinal studies have sufficient racial diversity to make  
13 comparisons between African-American and white girls (Adair & Gordon-Larsen, 2001;  
14 Freedman, et al., 2003; Onland-Moret, et al., 2005). Those that do have consistently found that  
15 African-American girls have an earlier median age of menarche than white girls and that  
16 African-American girls are heavier both pre and post menarche than white girls . However, none  
17 of these studies have data on girls younger than 5. Thus, there remains an open question about  
18 whether differences in timing of menarche and growth patterns in height and BMI are the same  
19 for African-American and white girls.

20 The aim of this study was to examine the association between timing of menarche on  
21 growth patterns in height and BMI from early childhood through late adolescence in a racially  
22 diverse, longitudinal sample. The onset of menarche was defined using race-specific cut points  
23 for early, mid and late onset menarche. Growth patterns were examined by chronological age and

1 age relative to menarche. This is the only study to our knowledge that tracks girls over the  
2 complete age range in a large sample of both African-American and white girls. Two specific  
3 research questions were addressed: (1) At what ages were BMI and/or height differences evident  
4 in the early, mid, and late onset menarche groups? (2) Were the associations between BMI  
5 and/or height and menarcheal timing similar across white and African-American girls?

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

## 12 Methods

### 13 *Sample*

14 The National Longitudinal Survey of Youth (NLSY79) began in 1979 with a  
15 representative sample of 2477 white and 1472 African-American women born between 1957 and  
16 1964 residing in the United States in December 1978. Respondents were interviewed annually  
17 between 1979 and 1994 and biennially thereafter. In 1986 the scope of the survey was expanded  
18 to include the Children of the NLSY79 (CNLSY79), biennial interviews about the biological  
19 children of the NLSY79 female respondents. Beginning in 1994, children over the age of 14  
20 were interviewed directly. The 1986-2006 waves of the CNLSY79 surveys were used in this  
21 study.

22 There were 3349 non-Hispanic white and African-American girls born before 1998 who  
23 were at least 8 years of age by the 2006 interview. Of these girls, 385 reported in the 2006

1 interview that they had not yet reached menarche. The eligible sample (N=2964) consisted of  
2 girls who were born before 1998, excluding girls who reported not having reached menarche in  
3 2006. The sample size was reduced by missing data for the following reasons: 1) not interviewed  
4 in 2006 and no information indicating that the girl had reached menarche by a previous interview  
5 (n=128); 2) girls (or mothers of girls) who could not recall their age of menarche in months  
6 (n=163); 3) missing data on height and weight at all interviews (n=6). The final sample consisted  
7 of 2667 girls (90% of the eligible sample): 1219 African-American girls and 1448 white girls.

8         The study used observations on height and weight at each interview conducted by the  
9 time of the girls' 20<sup>th</sup> birthday, for a total of 20479 person year observations. On average the  
10 African-American girls were interviewed 7.3 times and the white girls were interviewed 7.9  
11 times. There were 8978 person/age observations on African-American girls and 11501  
12 person/age observations on white girls. There was missing data on height and weight in 163  
13 (<0.8%) of the person/age observations.

#### 14 *Data Construction and Measures*

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

20         There is no standard definition of early, mid and late onset of menarche and existing  
21 studies use a variety of definitions (Adair & Gordon-Larsen, 2001; Biro, et al., 2001; Freedman,  
22 et al., 2002; Power, et al., 1997). The methods used in this study follow those used in other key  
23 longitudinal surveys, thus allowing for comparisons of results (Biro, et al., 2001; Demerath, et

1 al., 2004). Menarcheal timing groups were identified using the 25<sup>th</sup> and 75<sup>th</sup> percentile of the age  
2 distribution for each race. Among the African-American NLS girls, 25% reached menarche  
3 before 133 months, with a mean age of menarche of 123 months and median age of 126 months.  
4 The mid-onset African-American group, those between the 25<sup>th</sup> to 75<sup>th</sup> percentile, reached  
5 menarche between 133 and 152 months, with a mean of 143 months and median of 144 months.  
6 Late onset African-American girls (top 25%) reached menarche after 152 months, with mean of  
7 162 months and median of 159 months. Likewise, 25% of the white girls reached menarche  
8 before 141 months (mean of 131 months, median of 133 months), 50% reached menarche  
9 between 141 and 157 months(mean of 149 months, median of 149 months) , and 25% reached  
10 menarche after 157 months (mean of 167 months, median of 164 months). To provide further  
11 context for these internally generated cut points the 2005-2006 NHANES data were examined to  
12 determine the consistency with the NLS results. Although the NHANES data reports age of  
13 menarche only in years those data showed that 30% of African-Americans reported age<12  
14 years, 50% reported age=12 or 13 years, and 20% reported age>=14 years; whereas 19% of  
15 whites (excluding Mexican-Americans) reported age<12 years, 56% reported age=12 or 13  
16 years, and 25% reported age>=14 years. These results were therefore consistent with the NLS  
17 findings.

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

20 *Age at Interview.* Age in months at the date of the interview was available for all of the  
21 girls.

22 *Age in Months Relative to Age of Menarche.* Age in months relative to age of menarche  
23 was created by subtracting the age in months at menarche from the age in months at the

1 interview date. For example, a girl observed 12 months before menarche would have age relative  
2 to menarche of -12.

3 *Height and Weight:* Mothers of girls under the age of 14 were given the option to report  
4 their heights, converted to centimeters, and weights in pounds or have the interviewer complete  
5 these measurements. Approximately three-fourths of the heights and weights were directly  
6 measured. Heights and weights were completed with children wearing light clothing and without  
7 shoes. Interviewers were trained to conduct these measurements by the National Opinion  
8 Research Center at the University of Chicago. Girls 14 and over were also given the option of  
9 self-reporting. BMI scores were calculated using the CDC SAS program designed for this  
10 purpose. BMI is the relationship between weight and height, using the following formula:  $BMI =$   
11  $(\text{Weight in Pounds} / (\text{Height in inches}) \times (\text{Height in inches})) \times 703$ . A major advantage of  
12 using this program is that it includes cut points for biologically implausible values for heights  
13 and weights by age and sex, thus providing a reliable mechanism for data cleaning (Kuczmarski,  
14 et al., 2002).

### 15 *Analysis*

16 Longitudinal statistical techniques were used to estimate BMI and height as polynomial  
17 functions of age and age relative to menarche for each race/timing group. Likelihood ratio tests  
18 were used in conjunction with preliminary plots of the raw data to determine the degree of the  
19 polynomial in age for each growth model. In the case of height as a function of age relative to  
20 menarche, preliminary data analysis suggested that growth in height was linear before menarche  
21 and increased at a decreasing rate for the first few years after menarche until growth stopped.  
22 Therefore, height was specified as a linear function of age before menarche with a quadratic  
23 spline for age after menarche to capture the post-menarche tapering off of the growth rate. Wald

1 tests were used to test for differences across the early, mid and late groups within each race and  
2 to test for differences across race within each timing group.

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

18         The estimates were used to predict height and BMI by age and age relative to menarche  
19 for girls in each of the race/timing groups. The standard errors of these estimates were used to  
20 construct 95% confidence intervals around height/BMI for each age. These confidence intervals  
21 were then used to identify at which ages significant differences in predicted height and BMI  
22 occurred across race/timing groups.

1 BMI and height were imputed for children who were interviewed but had missing data  
2 under the assumption that the data were missing at random using Stata's multiple imputation of  
3 chained equations procedure. The imputation model included age, indicators for race, and  
4 indicators for menarcheal timing.

## 5 Results

### 6 *Model Selection*

7 In all cases the AICs for the mixed (random coefficient) models were lower than those of  
8 the fixed coefficient models. Furthermore, the results were not changed if imputed observations  
9 on missing BMI and height were included in the sample. Therefore, all results are reported based  
10 on estimates from the mixed model without using imputed values.

### 11 *BMI Results*

12 Figure 1a (African-American) and 1b (white) display the predicted BMIs by  
13 chronological age. Based on Likelihood Ratio tests BMI was specified as a cubic function of age  
14 for all race/timing groups. Within race Wald tests indicated that there were significant  
15 differences in the BMI-age profiles between the timing groups (i.e., early compared to mid  
16 compared to late) for both whites and African-American girls. Table 1 details the ages at which  
17 significant differences in predicted BMI were evident. Among African-American girls, early  
18 onset girls had higher BMIs than mid onset girls by age 3 years and mid onset girls had higher  
19 BMIs than late onset girls by age 4 years. These differences persisted through age 19 years.  
20 Among white girls, early onset girls had higher BMIs than mid onset girls by age 6 years and  
21 mid onset girls had higher BMIs by age 6 years. Again, these differences persisted through age  
22 19 years. Within each timing group, Wald tests indicated significant race differences in the  
23 BMI-age profiles. Among the early group, predicted BMI was significantly higher for African-

1 American as compared to white girls at all ages. By age 7 years the predicted BMI for African-  
2 Americans was higher than for whites in the mid onset groups. By age 8 predicted BMI was  
3 significantly higher for African-Americans than for whites in the late onset group. It should be  
4 noted that predicted BMIs for African-American girls in the early and mid onset groups were not  
5 only significantly higher than those in the comparable group for white girls, the predicted BMIs  
6 for both the early and mid onset African-American girls look like those found for early onset  
7 white girls. African-American girls in each of the timing groups enter adulthood already  
8 overweight (early: 28.2 (95% CI 27.4,29.0); mid:26.2 (95% CI 25.6,26.7); late: 25.195% CI  
9 (24.5,25.7), while for white girls only the early onset girls were overweight at 20 years (early:  
10 25.6 (95% CI 24.8,26.4); mid: 23.8 (95% CI 23.2,24.3); late 21.9 (95% CI 21.3,22.6).

11 Figure 2a and 2b display the predicted BMIs by age relative to menarche. Based on  
12 likelihood ratio tests, BMI was specified as a cubic function of age relative to menarche for all  
13 race/timing groups. Wald tests indicated that there were significant differences in the age profiles  
14 for white girls across the three timing groups. However, there was no significant difference in the  
15 age profile for mid and late African American girls, although the age profile of the early African  
16 American girls were significantly different from the two later groups. Table 1 details when  
17 significant differences in predicted BMI were evident as a function of menarche age. Among  
18 African-American girls there were significant differences prior to menarche but not post  
19 menarche. Early onset girls had higher BMIs 7 to 10 years prior to menarche and mid onset girls  
20 had higher BMIs than late onset girls 9 and 10 years prior to menarche. Among white girls, early  
21 onset girls were heavier than mid onset girls 9 and 10 years prior to menarche, but at no other  
22 time. The pattern was different for late onset white girls as late onset girls had lower BMIs than  
23 mid onset girls pre and post menarche. Beginning at one year prior to menarche and continuing

1 through the measurement period (5 years post menarche) late onset white girls were lighter than  
2 mid onset white girls. African-Americans in each timing group (early, mid, and late) had  
3 significantly higher predicted BMIs than white girls when age was measured relative to  
4 menarche throughout childhood.

#### 5 *Height Results*

6       Based on Likelihood Ratio tests height was specified as a quadratic function of age for all  
7 race/timing groups. Within race Wald tests indicated that there were significant differences in the  
8 predicted height-age profiles between the timing groups (i.e., early compared to mid compared to  
9 late) for both whites and African-American girls. Table 2 details the ages at which significant  
10 differences in predicted heights were evident. By age 4 early onset African-American girls were  
11 taller than African-American mid and late onset girls and mid-onset African-American girls were  
12 taller than late-onset African-American by age 5 years. By age 16 years mid onset African-  
13 American girls were taller than early onset girls and by age 18 years late onset African-American  
14 girls were taller than early onset girls. There were no differences in the predicted heights of the  
15 mid and late onset African-American girls. By age 5 years white early onset girls were taller than  
16 mid and late onset girls and white mid onset girls were taller than late onset girls by age 5 years.  
17 The predicted height differences between the early and mid white girls were no longer significant  
18 starting at age 13 years. By age 16 years there were no significant differences between mid and  
19 late onset white girls, although by age 20 years the late onset girls were significantly taller than  
20 the early onset white girls. Within each timing group, Wald tests indicated significant race  
21 differences in the predicted height-age profiles. African-American early onset girls were taller  
22 than white early onset girls by age 5 years; mid-onset African-American girls were taller than  
23 white mid-onset girls by age 7 years; and late-onset African-American girls were taller than

1 white late-onset girls by 10 years. By age 17 years white early onset girls were taller than  
2 African-American early onset girls; by age 19 years white mid-onset girls were taller than  
3 African-American mid-onset girls; and by age 17 years white late-onset girls were taller than  
4 African-American late-onset girls

5 Figure 3a and 3b display the height in inches by age relative to menarche. Predicted  
6 height was specified as a linear function until menarche with a quadratic spline thereafter for all  
7 groups. Wald tests indicated that there were significant differences in the age profiles for both  
8 racial groups across the three timing groups. Table 2 details the ages at which significant  
9 differences in predicted heights relative to age of menarche were evident. Within each racial  
10 group early onset girls predicted heights were always lower than the mid and late onset girls.  
11 Mid and late onset African-American girls were not significantly different by 2 years post  
12 menarche and for white girls the mid and late onset groups were similar by 3 years post  
13 menarche. Comparisons across racial groups show significant differences across race within  
14 timing groups. Predicted heights for white girls were always greater than their counterpart  
15 African-American group.

## 16 Discussion

17 This is one of the few longitudinal studies of differences in growth by timing of  
18 menarche that includes data on girls younger than 5 years of age. Many studies have found that  
19 girls who mature early are taller and heavier in middle childhood (Herman-Giddens, 2006;  
20 Herman-Giddens, Kaplowitz, & Wasserman, 2004; Power, et al., 1997) but few have been able  
21 to examine the age at which these differences first become apparent. Freedman et al. (Freedman,  
22 et al., 2003) found differences in BMI by menarcheal timing by age 5-9 years among white and  
23 African-American girls. Berkey et al. (Berkey, et al., 2000) also found differences in BMI by age

1 6 years of age in a small cohort of white girls and Lee found them by 3 years. Our findings  
2 confirmed these results for white girls and expand what we know about African-American girls.

3         Significant differences in BMI between early and mid onset African-American girls were  
4 found by 3 years of age and between early and mid onset white girls by 6 years. Significant  
5 height differences were evident by 5 years of age when comparing early to mid onset and mid  
6 onset to late onset girls in both race groups. These results suggest that the pathway through  
7 which these growth patterns and maturation differences originate must begin in early childhood.  
8 These results also support recent research that links childhood obesity to an earlier maturation.  
9 Obesity is thought to play a determining role in the age of menarche as body fat may exert a  
10 permissive effect on pubertal development through leptin released from adipocytes (Roemmich  
11 & Rogol, 1999). Leptin may signal the hypothalamic centers controlling satiety, energy  
12 expenditure, and regulation of sex hormones, cortisol, and growth hormone. However these  
13 results also raise the question as to whether there is a third factor operating to bring about both an  
14 increased childhood BMI and early sexual maturation. One possible alternative explanation is  
15 that girls exposed to chronic stressful environments may have chronic activation of the HPA  
16 axis, which could produce increased body fat, early adrenarche and puberty (Chang, Tzeng,  
17 Cheng, & Chie, 2000; Cizza, et al., 2001; L. D. Dorn & Rotenstein, 2004; Terasawa &  
18 Fernandez, 2001). Further work is needed to test these alternative hypotheses.

19         There are few papers that examine growth measures by age relative to menarche. The  
20 FELS study (Demerath, et al., 2004) found no difference by timing of menarche in BMI prior to  
21 menarche for white girls but found differences post menarche, leading them to conclude that  
22 obesity was a consequence not a determinant of menarche. Our results were different and suggest  
23 that there were significant BMI differences pre menarche across all timing groups in African-

1 American girls and between early and mid/late white girls, but not post menarche in these  
2 groups. The late onset white girls were significantly lighter than all other groups of girls, both  
3 before and after menarche. With respect to heights, early onset girls were always shorter than  
4 mid onset girls while mid onset girls were shorter than late onset girls until 1 to 2 years post  
5 menarche.

6         There are four notable differences when comparing these results across race. First, BMI  
7 and height differences by menarcheal timing were evident earlier in African-American girls  
8 when compared to white girls. Second, the BMIs of early onset African-American girls were  
9 very high and there were no comparable values for white girls. Third, late onset white girls have  
10 significantly lower BMIs than any other grouping of either African-American or white girls. And  
11 finally, 75% of the African-American girls have predicted BMI ranges that are greater than or  
12 comparable to the early onset white girls, with approximately 50% of the African-American girls  
13 having an age of menarche within the range of early onset white girls. This suggests that the  
14 majority of African-American females may be experiencing childhood growth patterns that have  
15 been linked to significant chronic health problems as (white) females age. This is a new finding  
16 that warrants further investigation and if pursued, may provide new insights into the origins of the  
17 well-documented health disparities between African-American and white females.

18         There are limitations to this study. The most significant weakness is that age of  
19 menarche was self- or mother-reported within two-year windows (L. Dorn, Dahl, Woodward, &  
20 Biro, 2006; L. D. Dorn, 2006). Although this is better than studies in which age of menarche is  
21 asked of adult women, many years past the event, it is still less accurate than more frequent data  
22 collection and objective measures such as hormone levels or physical exam. Future research  
23 could also benefit from more objective measures of adiposity, including waist-to-hip ratios.

## Conclusions

1  
2           Differences in BMI and height by timing of menarche began in early childhood. This  
3 suggests that growth acceleration is linked to maturational timing either through a direct causal  
4 path or early maturation and growth acceleration are the result of a very early common pathway.  
5 These results also provide evidence that higher BMIs are an antecedent to maturation not a  
6 consequence. Since higher BMIs in childhood are associated with early ages of menarche, which  
7 in turn are associated with health problems in later life, it is important to begin interventions  
8 directed at girls at risk for overweight in early childhood. This is of particular concern for  
9 African-American girls as they have higher BMIs at younger ages and experience menarche at  
10 earlier ages than white girls.

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**Table 1. Age of significant differences in predicted BMI**

<b>Comparison within race</b>	<b>Chronological Age</b>		<b>Age relative to Menarche</b>	
	African American	White	African American	White
Early Onset BMI > Mid-Onset BMI	3 → 20 yrs of age	6 → 20 yrs of age	10 yrs before → 7 yrs before	10 yrs before → 9 yrs before
Mid-Onset BMI > Late Onset BMI	4 → 18 yrs of age	6 → 20 yrs of age	10 yrs before → 9 yrs before	1 yr before → 5 yrs after
<b>Comparison across race</b>				
African-American early onset BMI > white early onset BMI	1 → 20 yrs of age		10 yrs before → 5 yrs after	
African-American mid-onset BMI > white mid-onset BMI	7 → 20 yrs of age		10 yrs before → 5 yrs after	
African-American late onset BMI > white late onset BMI	8 → 20 yrs of age		10 yrs before → 5 yrs after	

**Table 2. Age of significant differences in predicted height (ht)**

<b>Comparison within race</b>	<b>Chronological Age</b>		<b>Age relative to Menarche</b>	
	African American	White	African American	White
Early onset ht > mid-onset ht	4 → 13 yrs of age	5 → 12 yrs of age	-	-
Early onset ht < mid-onset ht	16 → 20 yrs of age	-	10 yrs before → 5 yrs after	10 yrs before → 5 yrs after
Mid-onset ht > late onset ht	5 → 16 yrs of age	5 → 15 yrs of age	-	-
Mid-onset ht < late onset ht	-	20 yrs of age	10 yrs before → 1 yr after	10 yrs before → 2 yrs after
<b>Comparison across race</b>				
African-American early onset ht > white early onset ht	5 → 12 yrs of age		-	
African-American early onset ht < white early onset ht	17 → 20 yrs of age		10 yrs before → 5 yrs after	
African-American mid-onset ht > white mid-onset ht	7 → 11 yrs of age		-	
African-American mid-onset ht < white mid-onset ht	19 → 20 yrs of age		10 yrs before → 5 yrs after	
African-American late onset ht > white late onset ht	10 → 11 yrs of age		-	
African-American late onset ht < white late onset ht	17 → 20 yrs of age		10 yrs before → 5 yrs after	

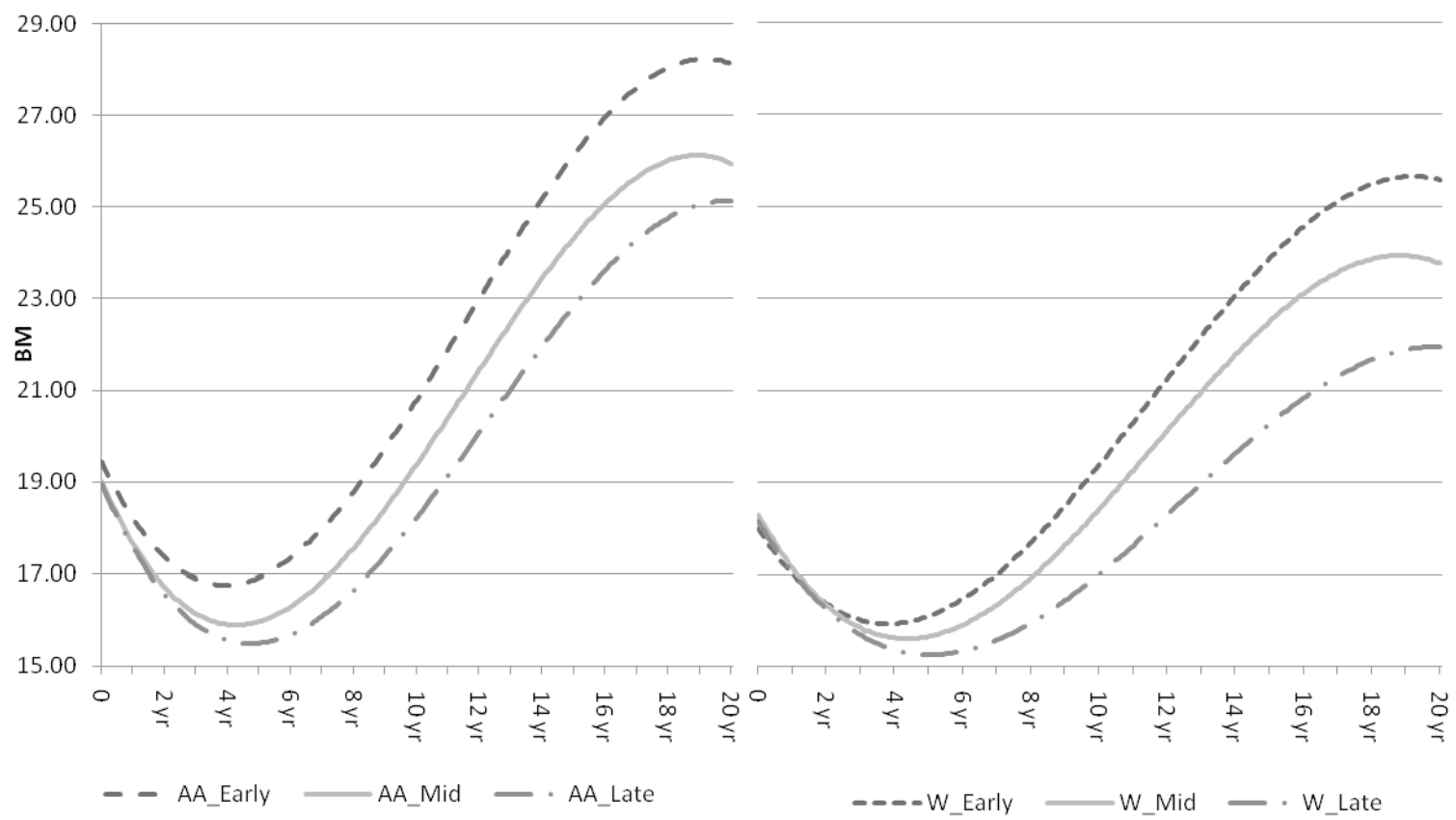


Figure 1a: BMI by age in years & Menarche Timing, African-American

Figure 1b: BMI by age in years & Menarche Timing, White



Figure

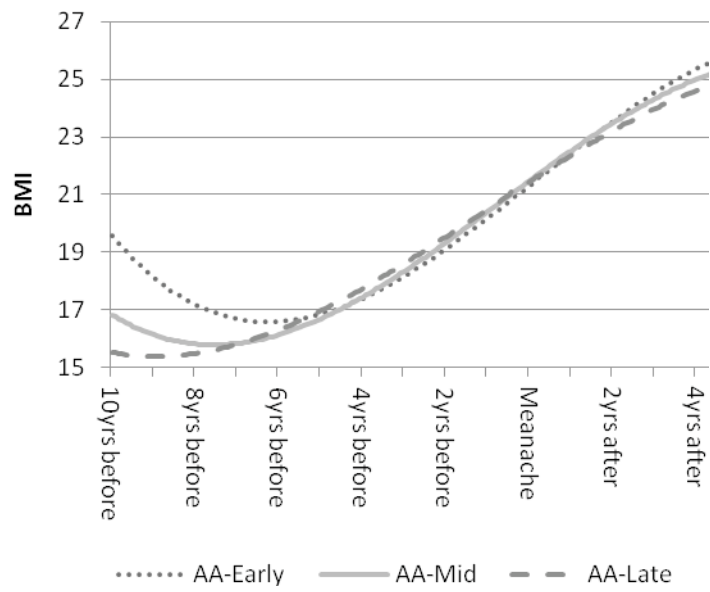


Figure 2a: BMI relative to menarche, African-American

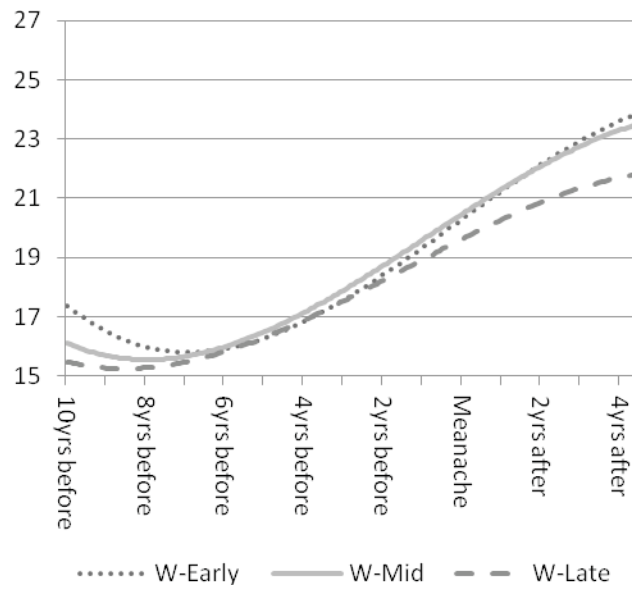


Figure 2b: BMI relative to menarche, White

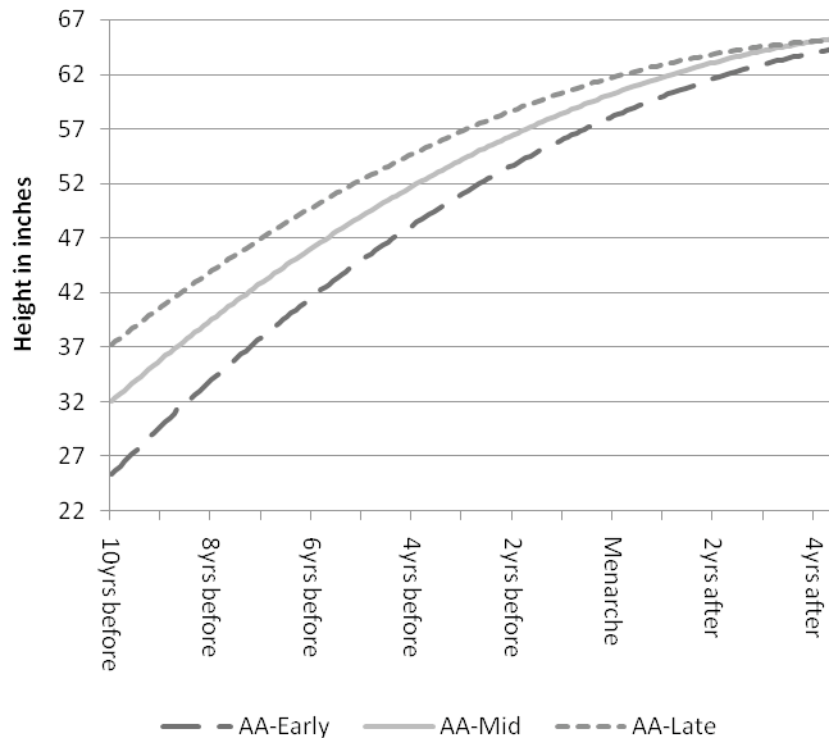


Figure 3a: Height relative to age of menarche, African-American

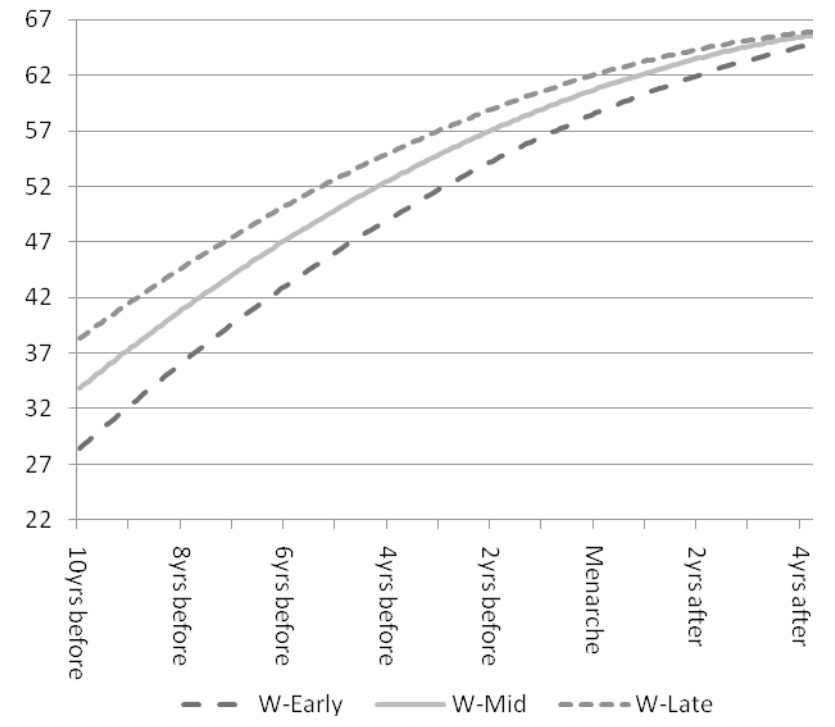


Figure 3b: Height relative to age of menarche, White