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Relative Weight and Race Influence Average Age at Menarche: Results From Two Nationally Representative Surveys of US Girls Studied 25 Years Apart

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ABSTRACT. *Objectives.* 1) To establish with nationally representative US data whether menarche occurred earlier in the 1990s than it had 25 years before. 2) To assess whether the occurrence of menarche in relation to weight status and race had changed over this time period.

Methods. Relative weight, race, and menarcheal status of girls in the National Health Examination Survey cycles II and III (1963–1970) were compared with results from the Third National Health and Nutrition Examination Survey (1988–1994). Probit analysis was used to determine the average age at menarche during the 2 survey periods. Logistic regression was used to assess the association of relative weight to likelihood of having reached menarche.

Results. The average age at menarche dropped from 12.75 to 12.54 years, and the percentage of girls between 10 and 15 years old who were above the 85th percentile for body mass index increased from 16% to 27% over the 25 years between the 2 surveys. Higher relative weight was strongly associated with increased likelihood of having reached menarche after controlling for age and race. Black girls had a lower average age at menarche than did white girls, which was independent of the effect of relative weight.

Conclusions. These analyses from 2 nationally representative samples of US girls suggest a drop of about 2½ months in the average age of menarche during the time period between 1963–1970 and 1988–1994. This was paralleled by a concurrent shift in the population distribution of body mass index z-score toward higher relative weights. *Pediatrics* 2003;111:844–850; *puberty, menarche, adolescents, obesity, overweight, body mass index, national surveys*

ABBREVIATIONS. PROS, Pediatric Research in Office Settings; BMI, body mass index; NHES, National Health Examination Survey; NHANES III, Third National Health and Nutrition Examination Survey; CDC, Centers for Disease Control and Prevention; CI, confidence interval.

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Considerable attention has been given in the popular press to the issue of early puberty.^{1–3} Much of this interest appears to have been sparked by 2 reports from the Pediatric Research in Office Settings (PROS) study.^{4,5} This study of ~17 000 3- to 12-year-old girls studied in pediatricians' offices during 1992 and 1993 found that the average age at menarche, based on a cross-sectional probit analysis, was 12.16 years in African-American girls and 12.88 years in white girls.⁴ Relative body weight, assessed as body mass index (BMI), was associated with breast development.⁵ Heavier girls were more likely to exhibit breast development than were leaner girls, an effect that was stronger for white girls than for African-American girls.⁵ Based on the results of the PROS study, it has been suggested that the clinical definition of precocious puberty be revised downward.⁶

The average age at menarche of girls in the United States and Europe has declined from an average of greater than 14 years before 1900⁷; this decline is generally attributed to improved nutrition and socioeconomic status of the population.⁸ However, the data to support this conclusion derive primarily from small, nonrepresentative samples, with age at menarche often collected retrospectively. In 1973, the average age at menarche in the United States, investigated using nationally representative data from the National Health Examination Survey (NHES), was reported as 12.76 years; stratified by race, the average age at menarche was calculated as 12.80 years for whites, and 12.52 years for blacks.⁹ Racial differences in maturational timing have been observed consistently in nationally representative and clinical samples, across time, and using different study designs.^{10–12}

That adiposity is associated with maturational timing is well-established, although the mechanism is not.^{11–15} Whereas Frisch's hypothesis of a critical level of body fat as a necessary trigger for menarche^{15,16} has been controversial,^{17–19} the association between increased relative weight and earlier menarche has been documented in both cross-sectional and longitudinal studies.^{11,12,14,15,20}

The prevalence of obesity in children in the United States is increasing. In the Third National Health and Nutrition Examination Survey (NHANES III) conducted between 1988 and 1994, 11% of children 6 to 17 years old were overweight (BMI >95th percentile).²¹ This represented an increase of ~5% from the

NHES conducted during the 1960s.²² Differences in overweight prevalence were apparent by race during NHANES III; non-Hispanic black and Mexican American youth were more likely to be overweight than were non-Hispanic whites.²¹

Despite recent increases in the prevalence of overweight among US children, and the long understood association between sexual maturation and adiposity,^{23,24} the role of relative weight as a possible explanatory factor for the secular trend toward earlier puberty has been advanced but not empirically evaluated. Our objectives for this report were 2-fold: first, to establish with nationally representative US data whether menarche occurred earlier in the 1990s than it had 25 years earlier; and second, to assess whether the occurrence of menarche in relation to race and weight status had changed over this time period.

METHODS

Data from 2 surveys representative of the civilian noninstitutionalized US population were used in these analyses. Cycles II and III of the NHES were conducted between 1963–1965 and 1966–1970 (children ages 6–11 years old, and youth ages 12–17 years old, respectively); in this report, we will use the term NHES to indicate cycles II and III combined unless we specify the cycle to which we are referring. The NHANES III was conducted between 1988–1994, and included subjects in infancy through old age. Survey design and operations have been described in detail elsewhere.^{25–27} Data from NHES are available from the Inter-University Consortium for Political and Social Research, P.O. Box 1248, Ann Arbor, Michigan 48106. Data from NHANES III are available online at <http://www.cdc.gov/nchs/nhanes.htm>.

The analytic sample used in this report included 1109 girls 10 years old and above at last birthday from NHES cycle II, of which 1076 (97%) had complete data, and 2218 girls 12 to 15 years old at last birthday from cycle III, of which 2196 (99%) had complete data. The 2 cycles, when combined, provide a sample of 3272. There were 1025 girls included in cycle III who had also been surveyed in cycle II. Thirty-nine girls from NHES cycle II who were older than 12 years at the time of examination were excluded from the cycle-specific logistic regression analyses.

The NHANES III analytic dataset included girls between the ages of 10 years, zero months, and 15 years, 11.99 months who had complete data on menarcheal status, age at examination, height, weight, and race. All 15-year-old girls in NHANES III were menarcheal, as were 98% of 15-year-old girls in NHES. Therefore, we restricted analyses to girls who were between the ages of 10 and 15 at their last birthday. A lower limit of age 10 was applied for comparability between the 2 samples. In NHANES III, girls under 10 years old were not directly questioned about menarcheal status. Because <4% of 10-year-old girls in NHANES III had reached menarche, the proportion of girls *younger* than 10 who were menarcheal would likely have been very small. The NHANES III sample included 1414 girls who were between 10 and 15 years old at last birthday. Sixty-five girls, evenly distributed across age, were missing data on menarcheal status. An additional 23 girls were missing data on either height or weight, providing 1326 (94%) for inclusion in this report.

Menarcheal status was determined by a single question. NHES cycle II asked of parents “Have her monthly periods started?” and NHES cycle III asked of parents “Have her monthly periods (menstruation) started?” In NHES cycle III, the girl herself also reported on her menarcheal status and percentage of agreement between the self and parental reports was high (96% agreement, Kappa = 0.93; S. E. Anderson, unpublished observations). In NHANES III, girls themselves were asked, “How old were you when your periods or menstrual cycles started?” with a response option of “have not started yet.” Data were coded to indicate whether or not each girl had reached menarche at the time of the interview.

The physical examination in NHES and NHANES III included a standardized measurement protocol for weight and standing height. BMI was calculated as weight in kilograms divided by

height in meters squared. Relative weight was defined based on an age-specific BMI z-score for each girl derived using the Centers for Disease Control and Prevention’s (CDC) BMI-for-age percentiles.²⁸ BMI z-score was calculated as $((\text{BMI}/M)^L - 1)/L * S$, where M is the median, S is the standard deviation, and L is a skewness parameter.²⁸ The LMS constants are available at the CDC’s website: www.cdc.gov/growthcharts. A BMI z-score above 1.036 corresponds with a BMI-for-age above the 85th percentile, and a z-score above 1.645 indicates a BMI above the 95th percentile. These cut-points were used to calculate the prevalence of girls who were at risk for overweight (>85th percentile) or overweight (>95th percentile) in the NHES and NHANES III populations. The cut-points and the accompanying terminology are based on recommendations from an expert consensus conference that *overweight* in children 2 through 20 years old be defined as a BMI above the 95th percentile for the child’s age and sex, and *at risk for overweight* be defined as a BMI above the 85th percentile.^{21,29,30}

In our analyses, race was coded as black, white, or other. In NHES, race was determined by interviewer observation and confirmed, when possible, by birth certificate; options were “white,” “Negro,” or “other.” In NHANES III race was self-reported; options were “white,” “black,” and “other.” Ethnicity was assessed in NHANES III, but there was no comparable categorization available in NHES. Hispanics are included within the white, black, and other racial categories in these analyses based on subject’s self-report of race (NHANES III) or as determined by interviewer assessment of race (NHES).

To account for the complex survey design, sample weights were used in all analyses.³¹ Prevalence estimates and standard errors for each age and survey were calculated with SUDAAN version 7.5 (Research Triangle Institute, Research Triangle Park, NC). Independent samples *t* tests were conducted to compare BMI z-scores for premenarcheal and postmenarcheal girls for each age group and survey. All tests were performed at the 2-sided .05 level of significance.

To calculate the average age at menarche in the United States during 1963–1970 (NHES) and 1988–1994 (NHANES III) we fit probit models to the proportion of girls at each age who had reached menarche.³² This method, sometimes referred to as the status quo method,^{9,14} was used to calculate the average age at menarche in the population during NHES and NHANES III. The status quo method requires a cross-sectional sample of girls who are between the ages when menarche typically occurs. The percentage of girls at each age who are menarcheal was determined; these percentages were then fit to a cumulative normal curve where the population median age at menarche is the corresponding age at which 50% of girls in the population would be predicted to be menarcheal. We used a probit model, with age in months as the dependent variable, to calculate the population median age at menarche and the 95% fiducial interval for the 2 survey periods. Throughout this report we will use the term *average age at menarche* to refer to the estimated median age at menarche, and will henceforth refer to the 95% fiducial interval as the *95% confidence interval* (CI).³³ Models were fit with PROC PROBIT, SAS version 8.1 (SAS Institute, Cary, NC).

Logistic regression was used to model the association between the log odds of being menarcheal and BMI z-score, age in months, and race. BMI z-score and age were continuous variables and race was a categorical variable (white, black, other), with white as the reference category. The racial category “other” was included in the model but was not interpreted. To account for the complex multistage sampling design, SUDAAN was used to construct individual models by survey period (NHES cycle II, NHES cycle III, NHANES III). Interactions between race and BMI z-score were assessed by testing the statistical significance of interaction terms added to the logistic regression models.

To assess the effect of changes in the distribution of BMI z-score and race between NHES and NHANES III on the average age at menarche in the United States we used a standardization approach. We combined the data from the 2 cycles of NHES, and using sample weights, estimated the association between the log odds of being menarcheal and BMI z-score, age, and race with PROC LOGISTIC in SAS. Although the standard errors would not be accurate because of the complex design of the survey, the parameter estimates from this model are assumed to be valid.³⁴ Using the NHANES III data and this combined NHES logistic regression model we calculated, for each girl in NHANES III, a predicted probability of having reached menarche given her age,

TABLE 1. Characteristics of Sample Participants, Girls 10 to 15 Years Old in the NHES (1963–1970) and the NHANES III (1988–1994)

| Age (Years) | NHES | | | | | | NHANES III | | | | | |
|-------------|------|---------|--------------|-------------|--------------------------|-------------|------------|---------|--------------|--------------|--------------------------|-------------|
| | N | % White | Height (cm) | Weight (kg) | BMI (kg/m ²) | BMI z-score | N | % White | Height (cm) | Weight (kg) | BMI (kg/m ²) | BMI z-score |
| 10 | 570 | 86.0 | 141.01 (.31) | 35.16 (.40) | 17.54 (.16) | -.11 (.06) | 232 | 77.3 | 142.68 (.65) | 37.91 (1.29) | 18.43 (.48) | .13 (.13) |
| 11 | 506 | 86.9 | 147.32 (.30) | 39.88 (.46) | 18.24 (.18) | -.10 (.06) | 261 | 78.2 | 150.16 (.68) | 44.15 (1.13) | 19.42 (.39) | .26 (.12) |
| 12 | 540 | 85.3 | 154.79 (.31) | 46.65 (.38) | 19.36 (.12) | .08 (.04) | 223 | 68.9 | 155.19 (.72) | 48.85 (1.17) | 20.19 (.47) | .25 (.12) |
| 13 | 575 | 85.8 | 158.34 (.32) | 50.40 (.48) | 20.02 (.15) | .10 (.04) | 210 | 76.2 | 159.50 (.87) | 55.68 (1.60) | 21.82 (.62) | .46 (.14) |
| 14 | 581 | 85.9 | 160.97 (.30) | 54.13 (.40) | 20.85 (.13) | .17 (.03) | 211 | 83.1 | 160.87 (.71) | 58.27 (1.50) | 22.48 (.54) | .54 (.11) |
| 15 | 500 | 86.2 | 161.62 (.49) | 56.34 (.54) | 21.52 (.18) | .17 (.05) | 189 | 81.6 | 162.76 (.67) | 58.07 (1.08) | 21.91 (.44) | .28 (.11) |
| Overall | 3272 | 86.0 | NA* | NA | NA | NA | 1326 | 77.8 | 155.35 (.42) | 50.65 (.70) | 20.74 (.24) | .32 (.06) |

Mean (standard error) is presented. SUDAAN was used to generate estimates and standard errors. NHES cycle II: ages 10,11; NHES cycle III: ages 12–15. Sample size presented is the unweighted sample size; standardized sample weights were used in all analyses. Age is age at last birthday. BMI z-score based on the revised CDC BMI for age growth charts.²⁸

* Not available for NHES.

race, and BMI z-score. We then fit a probit model to the mean probability of having reached menarche for a given age, based on the NHANES III predicted probabilities, and calculated the predicted average age at menarche.

RESULTS

The total sample size for NHES is more than twice that in NHANES III (Table 1). The percentage of the population of US girls that were classified as white decreased from 86% to 78% over the ~25 years between the surveys. The BMI of girls between 10 and 15 years old in the United States also increased between NHES and NHANES III. Figure 1 shows the distribution of BMI z-scores during each survey period. The percentage of girls between 10 and 15 years old who were above the 85th percentile for BMI increased from 16% in NHES to 27% in NHANES III. The mean BMI z-score increased from 0.05 to 0.32. The distribution of BMI z-scores shifted toward higher relative weights and became more skewed. Black girls showed a larger increase in relative weight between the 2 surveys; for blacks, mean BMI z-score increased from 0.05 in NHES to 0.50 in NHANES III, for whites the increase was from 0.05 to 0.31 (data not shown).

In the United States, the percentage of girls at each age who had reached menarche increased between NHES and NHANES III (Table 2). A greater proportion of black girls experienced menarche before age 12 compared with white girls, with a similar pattern of earlier menarche over the time period between the 2 surveys. The average age at menarche in the United States dropped from 12.75 years (95% CI: 12.69–12.82 years) in NHES to 12.54 years (95% CI: 12.44–12.64 years) in NHANES III. Within racial groups, in NHES the average age at menarche was estimated to be 12.80 years (95% CI: 12.73–12.87 years) for whites and 12.48 years (95% CI: 12.28–12.67 years) for blacks. In NHANES III the average age at menarche was estimated to be 12.60 years (95% CI: 12.48–12.71 years) for whites and 12.14 years (95% CI: 11.87–12.39 years) for blacks.

In both surveys and at all ages, girls who had reached menarche had a higher mean BMI z-score than girls who had not reached menarche (Table 3). Girls under 12 years old who had reached menarche had a higher mean BMI z-score compared with girls who had not reached menarche: 0.93 units higher in NHES and 0.83 units higher in NHANES III (inde-

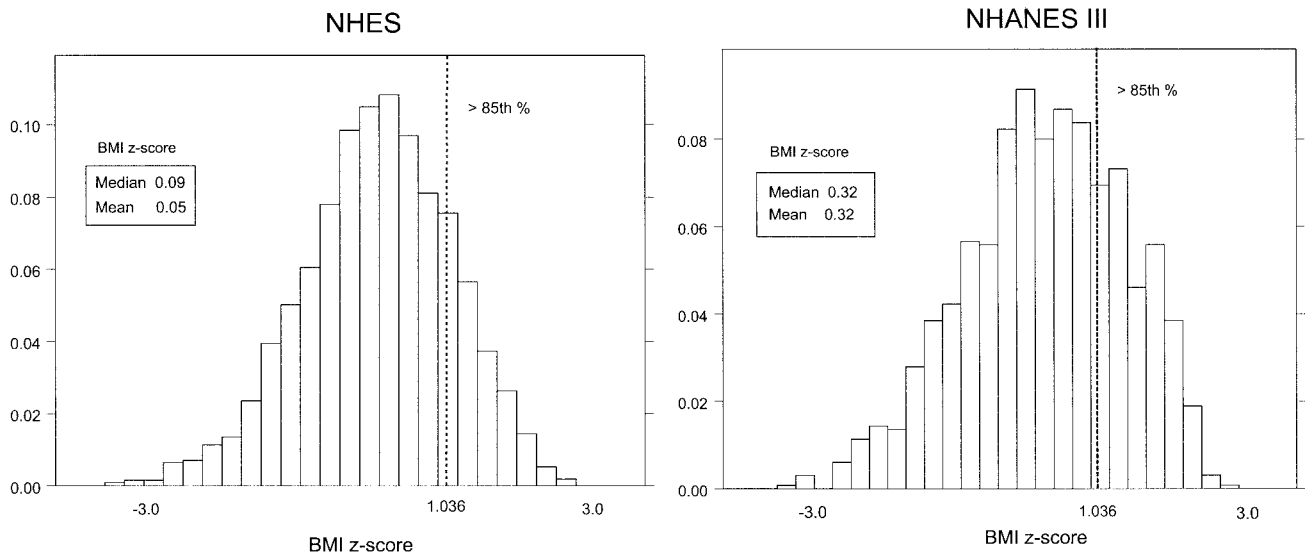


Fig 1. Distributions of BMI z-score for girls 10 to 15 years old in the NHES 1963–1970 and the NHANES III 1988–1994. BMI z-score based on the revised CDC BMI for age growth charts.²⁸ The 85th percentile corresponds to a BMI z-score of 1.036. One girl with a BMI z-score of -4.99 was not included in the NHANES III histogram, but was included in all analyses reported.

TABLE 2. Percentage of Girls Who Had Reached Menarche in the NHES (1963–1970) and the NHANES III (1988–1994)*

| | NHES | | | | NHANES III | | |
|-------------------------|------|-----|------------------------|--------------|------------|------------------------|-------------|
| | Age | N | Percent Menarcheal (%) | SE | N | Percent Menarcheal (%) | SE |
| White | 10 | 4 | 0.81 | .42 | 8 | 4.01 | 3.59 |
| | 11 | 49 | 11.58 | 1.80 | 31 | 12.34 | 3.60 |
| | 12 | 195 | 42.69 | 2.56 | 65 | 49.49 | 6.04 |
| | 13 | 355 | 72.95 | 2.28 | 104 | 72.78 | 6.81 |
| | 14 | 437 | 91.39 | 1.97 | 131 | 98.41 | 1.01 |
| | 15 | 414 | 98.19 | 0.55 | 113 | 100 | — |
| Average age at menarche | | | 12.80 y | 12.73–12.87 | | 12.60 y | 12.48–12.71 |
| Black | 10 | 3 | 3.82 | 2.12 | 5 | 4.38 | 1.90 |
| | 11 | 16 | 21.64 | 5.76 | 25 | 31.53 | 6.10 |
| | 12 | 47 | 53.34 | 7.26 | 52 | 57.54 | 7.89 |
| | 13 | 66 | 74.06 | 6.84 | 76 | 93.45 | 2.75 |
| | 14 | 93 | 93.53 | 2.03 | 71 | 97.00 | 2.09 |
| | 15 | 71 | 99.04 | .91 | 70 | 100 | — |
| Average age at menarche | | | 12.48 y | 12.28–12.67 | | 12.14 y | 11.87–12.39 |
| Total population | 10 | 7 | 1.22 | 0.41 | 13 | 3.89 | 2.80 |
| | 11 | 65 | 12.80 | 1.87 | 57 | 14.26 | 2.98 |
| | 12 | 245 | 44.42 | 2.35 | 129 | 51.14 | 5.09 |
| | 13 | 422 | 73.16 | 2.24 | 186 | 77.03 | 5.56 |
| | 14 | 531 | 91.70 | 1.75 | 208 | 98.15 | .88 |
| | 15 | 490 | 98.32 | 0.51 | 193 | 100 | — |
| Average age at menarche | | | 12.75 y† | 12.69–12.82‡ | | 12.54 y | 12.44–12.64 |

SE indicates standard error.

* Sample size presented (N) is the unweighted number of girls at that age who had reached menarche. Percentage menarcheal and SE were generated with SUDAAN. Average age at menarche uses the status quo method implemented through a probit analysis with age in months as the dependent variable.

† Estimate is age at which 50% of girls are predicted to be menarcheal.

‡ 95% confidence (fiducial) interval from probit analysis.

TABLE 3. Mean BMI z-Score in Pre- and Postmenarcheal Girls in the NHES (1963–1970) and the NHANES III (1988–1994)*

| Age (Years) | NHES | | | | | NHANES III | | | | |
|-------------|---------------|------------------|----------------|------------------|---------------|---------------|------------------|----------------|------------------|--------------|
| | Premenarcheal | | Postmenarcheal | | t (P Value)‡ | Premenarcheal | | Postmenarcheal | | t (P Value)‡ |
| | N | BMI z-Score (SE) | N | BMI z-Score (SE) | | N | BMI z-Score (SE) | N | BMI z-Score (SE) | |
| 10 | 563 | −0.12 (.06) | 7 | .93 (.30) | 3.41 (.0028) | 220 | .08 (.13) | 12 | 1.57 (.12) | 7.37 (.0000) |
| 11 | 441 | −0.22 (.05) | 65 | .75 (.13) | 8.78 (.0000) | 204 | .17 (.13) | 57 | .83 (.18) | 2.84 (.0071) |
| 12 | 295 | −0.28 (.07) | 245 | .52 (.06) | 7.82 (.0000) | 96 | −.15 (.23) | 127 | .63 (.09) | 2.99 (.0050) |
| 13 | 153 | −0.56 (.07) | 422 | .34 (.04) | 10.83 (.0000) | 29 | −.33 (.29) | 181 | .71 (.10) | 3.70 (.0007) |
| 14 | 50 | −0.85 (.13) | 531 | .26 (.04) | 8.57 (.0000) | 10 | −.45 (.57) | 201 | .56 (.11) | 1.79 (.0844) |
| 15 | 10 | −1.01 (.39) | 490 | .19 (.05) | 3.08 (.0059) | 0 | — | 189 | .28 (.11) | — |

SE indicates standard error.

* Mean (SE) is presented. SUDAAN was used to generate estimates and SEs. NHES cycle II: ages 10,11; NHES cycle III: ages 12–15. Sample size presented in table is the unweighted sample size; standardized sample weights were used in all analyses. Age is age at last birthday. BMI z-score based on the revised CDC BMI for age growth charts.²⁸

‡ P value of t test comparing BMI z-score in pre- and postmenarcheal girls of the same age.

pendent samples t test, $P < .0001$ at each time period).

In logistic regression models for all individual survey periods (NHES cycle II, NHES cycle III, and NHANES III), increased BMI z-score was associated with increased likelihood of having reached menarche, after adjusting for age and race (Table 4). Black race was an independent predictor of likelihood of having reached menarche in the NHES cycle II and NHANES III logistic regression models; in NHES cycle III the association was not statistically significant, although the directionality was the same. There was no evidence of an interaction between race (black versus white) and BMI z-score during any survey period.

Based on the standardization of the NHANES III data to the association of menarcheal status with age, race, and BMI z-score in NHES, the predicted average

age at menarche in NHANES III was calculated to be 12.56 years (Table 5). This predicted value is very close to the average age of menarche of 12.54 calculated for NHANES III.

DISCUSSION

We undertook these analyses to calculate the average age at menarche from nationally representative samples of US girls, and to evaluate the influence of increases in BMI seen in the population over the time period between the 2 surveys. We found that the average age at menarche in the United States declined from 12.75 years to 12.54 years between the NHES and the NHANES III, and that relative weight was strongly associated with likelihood of having reached menarche. Our analyses are consistent with other reports indicating that, on average, black girls reach menarche sooner than white girls; additionally,

TABLE 4. Logistic Regression Models Predicting Menarcheal Status With Age, Race, and Relative Weight for the NHES Cycles II and III, 1963–1970 and the NHANES III 1988–1994

| Variable | Parameter Estimate | Standard Error | χ^2 Value | χ^2 Significance | Odds Ratio |
|--------------------------|--------------------|----------------|----------------|-----------------------|------------|
| BMI z-score | | | | | |
| NHES cycle II | 1.04 | .17 | 38.40 | .000 | 2.8 |
| NHES cycle III | 1.10 | .07 | 163.49 | .000 | 3.0 |
| NHANES III | .86 | .16 | 27.80 | .000 | 2.4 |
| Race: black versus white | | | | | |
| NHES cycle II | 1.01 | .34 | 9.08 | .003 | 2.7 |
| NHES cycle III | .31 | .19 | 2.70 | .100 | 1.4 |
| NHANES III | .76 | .31 | 5.83 | .016 | 2.1 |
| Age in years | | | | | |
| NHES cycle II | 2.66 | .41 | 41.42 | .000 | 14.3 |
| NHES cycle III | 1.54 | .09 | 267.94 | .000 | 4.7 |
| NHANES III | 1.81 | .16 | 130.87 | .000 | 6.1 |

All estimates are from SUDAAN. The model includes age, black race, other race, and BMI z-score. Other race was included in the models above, but estimates for other race are not presented.

TABLE 5. Predicted Probabilities for Having Reached Menarche Based on the NHES (1963–1970) Associations Between Menarche, Age, Race, and Relative Weight, and the NHANES III (1988–1994) Distributions of Age, Race, and Relative Weight

| | Predicted Proportion |
|-----------------------------------|----------------------|
| Age | |
| 10 | 0.04 |
| 11 | 0.18 |
| 12 | 0.47 |
| 13 | 0.80 |
| 14 | 0.95 |
| 15 | 0.99 |
| Predicted average age at menarche | 12.56 y* |

* Predicted average age at menarche from probit analysis; 95% CI: 12.45–12.67.

we found no evidence to indicate that the observed earlier age at menarche among black girls was attributable to a larger proportion of black girls being overweight.

Based on NHANES III, the most recent dataset representative of US girls from which estimates of the average age at menarche can be calculated, the average age at menarche of 12.54 years represents a decrease of $\sim 2\frac{1}{2}$ months over the 25 years between the 2 surveys. During the same time period, the percentage of 10 to 15-year-old girls in the United States who were above the 85th percentile for BMI increased from 16% to 27%.

Previous estimates of the average age at menarche using data from NHES have been published and our analyses agree well with those results despite slight differences in analytic approach.⁹ We are not aware of published estimates of the average age at menarche using NHANES III data, except for 1 brief report by Lee et al.³⁵ Data from the PROS study, collected between 1992 and 1993, indicated an average age at menarche of 12.9 years for whites and 12.2 years for blacks,⁴ slightly higher than our NHANES III estimates of 12.6 years for whites and 12.1 years for blacks. Although the NHANES III sample size is smaller than that of the PROS study, the NHANES III sample is nationally representative and includes girls over the full age range at which menarche occurs. The PROS study was conducted in pediatricians' offices and included girls only through age 12. Al-

though the status quo method can estimate the average age at menarche even when data are observed for only a portion of the age range over which menarche occurs, these estimates will be particularly sensitive to the assumption that the data fit a cumulative normal curve.³⁶

Our analyses of 2 nationally representative surveys provide estimates of the average age at menarche that can be validly compared across time. We used the CDC modified growth reference²⁸ to calculate BMI z-score in both surveys from measured height and weight. Use of a standard growth reference in the 2 surveys further increases the comparability of the results. Although it is possible that there is misclassification of menarcheal state, the status quo method is unlikely to be biased because it relies on the report of whether or not menarche, a salient event, has occurred.

Research consistently indicates that overweight is associated with earlier menarche.^{37–39} Girls with a higher percentage of body fat are more likely to reach menarche at a younger age than are leaner girls. Our cross-sectional analyses of pre- and postmenarcheal girls in NHES and NHANES III are supportive of this as well. At any age, and in both survey periods, postmenarcheal girls had a higher average relative weight compared with their premenarcheal peers. We observed a positive association between BMI z-score and likelihood of having reached menarche in both NHES and NHANES III. Based on the NHANES III logistic regression model, for 2 girls of the same age and race, 1 at the 50th percentile for BMI and the other at the 85th percentile, the heavier girl would be ~ 2.4 times more likely to have reached menarche than the leaner girl.

As has also been shown by others, race was an independent predictor for having reached menarche.^{11,12} Black girls were more likely than white girls to have reached menarche, after controlling for age and BMI z-score. Given that the black female population has shown a more dramatic rise in prevalence of overweight than has the white female population in the United States, one might hypothesize that the lower age at menarche seen in blacks is due only to increased body weight. However, our analyses do not support this conclusion. Race had

an independent effect on the likelihood of having reached menarche in the NHES cycle II and NHANES III models, after controlling for BMI z-score and age. In NHANES III, after controlling for age and BMI z-score, black girls were twice as likely to have reached menarche compared with white girls.

Our analyses of the most recent nationally representative data indicate that the secular trend of decreasing average age at menarche in the United States continues. Historically, many factors have been posited to contribute to the trend toward earlier age at menarche, including temperature and humidity, light, altitude, month of birth, nutrition, psychology, hygiene, and genetics.⁸ More recently, phthalates,⁴⁰ environmental estrogens,⁴¹ endocrine disruptors,⁴² perinatal growth,⁴³ single parenting,⁴⁴ and stress⁴⁵ have been implicated as contributors to the trend toward an earlier population average age at menarche. Whereas it is overly simplistic to assert that a lower population age at menarche is due to any single factor, the large increase in overweight in the United States during the later part of the 20th century likely represents a major contributor to the observed secular decrease in average age at menarche.

We hypothesized that had the population during NHES been "like" the population during NHANES III, in terms of BMI z-score and race, then the *predicted average age at menarche* during NHES would be similar to the 12.54 years calculated in NHANES III. To test this hypothesis, we calculated hypothetical predicted probabilities, using the NHANES III distributions of BMI z-score, race, and age and the NHES logistic regression model. The results of our analysis confirmed this hypothesis: the *predicted average age at menarche* during NHES was 12.56 years. This suggests that the actual decrease observed between NHES and NHANES III of ~2.5 months is as expected given the changes, particularly in overweight, in the US population between 1963 and 1994.

Several limitations of the current analyses are noteworthy. First, NHES was not a single survey. The data on 10- and 11-year-old girls (cycle II of NHES) were collected an average of 3 years before the data on 12- to 15-year-old girls (cycle III of NHES), and approximately one third of the girls studied in cycle II were restudied in cycle III. It was not possible to account for the complex sample design of the surveys with the data from cycles II and III combined. Therefore, the logistic regression models to determine the effect of relative weight status on log odds of being menarcheal were estimated separately for each cycle of NHES. Second, given that the sample size of NHANES III is less than one half that of NHES, estimates from NHANES III have larger standard errors compared with NHES, particularly when results are stratified by race. Third, BMI is not a direct measure of adiposity; however, when analyses were repeated using a cut-point of BMI above the 85th percentile, the interpretation of the results did not change. Fourth, there were some minor differences in methodology across the surveys: 1) menarcheal status was determined by self-report in

NHANES III, and by parental-report in NHES; however, in a subsample of NHES girls who had both parent report and self report of menarcheal status, the percent agreement was high; and 2) it is possible that definitions of race in the United States have changed slightly between NHES and NHANES III, although we assume that any misclassification caused by definitional changes will be much smaller than the shift in the distribution of race between the 2 survey periods. Finally, we believe that although a standardization to arrive at a *predicted average age at menarche* provides useful information in assessing the effect of increasing overweight on maturational timing in the United States, this analysis should not be interpreted as precluding the possible role of other environmental influences on menarche, nor as negating the independent effect of race.

CONCLUSIONS

Between the time of the NHES (1963–1970) and the NHANES III (1988–1994), the population average age at menarche in US girls dropped from 12.75 years to 12.54 years. During this same interval, the percentage of girls 10 to 15 years old with a BMI above the 85th percentile for age increased from 16% to 27%. Increased BMI is associated with increased likelihood of being menarcheal, adjusted for age and race. Additionally, black girls are more likely to reach menarche before white girls of the same age and relative weight. We found no evidence to suggest that the lower average age at menarche observed in blacks during both survey periods was due to a higher prevalence of overweight among black girls. The changes in relative weight and racial distributions that occurred in the US population represent a tenable explanation for the observed decrease in average age at menarche in the United States between these 2 nationally representative surveys.

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REFERENCES

1. Saltus R. Growing up too soon? *The Boston Globe*. October 10, 2000;Sect. E1
2. Lemonick MD. Teens before their time. *Time*. October 30, 2000:66–74
3. Belkin L. The making of an 8-year-old woman. *The New York Times Magazine*. December 2000;24:38–43
4. Herman-Giddens ME, Slora EJ, Wasserman RC, et al. 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
5. Kaplowitz PB, Slora EJ, Wasserman RC, et al. Earlier onset of puberty in girls: relation to increased body mass index and race. *Pediatrics*. 2001; 108:347–353
6. Kaplowitz PB, Oberfield SE, Drug and Therapeutics and Executive Committees of the Lawson Wilkins Pediatric Endocrine Society. Reexamination of the age limit for defining when puberty is precocious in girls in the United States: implications for evaluation and treatment. *Pediatrics*. 1999;104:936–941
7. Wyshak G, Frisch RE. Evidence for a secular trend in age of menarche. *N Engl J Med*. 1982;306:1033–1035

8. Zacharias L, Wurtman RJ. Age at menarche: genetic and environmental influences. *N Engl J Med*. 1969;280:868–875
9. Macmahon B. Age at menarche: United States. DHEW Publication. Rockville, MD: National Center for Health Statistics; 1973. Report No.: (HRA) 74-1615
10. Harlan WR, Harlan EA, Grillo GP. Secondary sex characteristics of girls 12 to 17 years of age: the U.S. Health Examination Survey. *Adolesc. Med*. 1980;96:1074–1078
11. Kimm SYS, Barton BA, Obarzanek E, et al. Racial divergence in adiposity during adolescence: the NHLBI growth and health study. *Pediatrics*. 2001;107(3). Available at www.pediatrics.org/cgi/content/full/107/3/e34
12. Wattigney WA, Srinivasan SR, Chen W, et al. Secular trend of earlier onset of menarche with increasing obesity in black and white girls: the Bogalusa Heart study. *Ethn. Dis*. 1999;9:181–189
13. Garn SM, Haskell JA. Fat and growth during childhood. *Science*. 1959;130:1711–1712
14. Zacharias L, Rand WM, Wurtman RJ. A prospective study of sexual development and growth in American girls: the statistics of menarche. *Obstet Gynecol Surv*. 1976;31:325–337
15. Frisch RE, Revelle R. Height and weight at menarche and a hypothesis of menarche. *Arch Dis Child*. 1971;46:695–701
16. Frisch RE. Body fat, puberty and fertility. *Biol Rev Camb Philos Soc*. 1984;59:161–188
17. Ellison PT. Skeletal growth, fatness, and menarchial age: a comparison of two hypotheses. *Hum Biol*. 1982;54:269–281
18. Scott EC, Johnston FE. Critical fat, menarche, and the maintenance of menstrual cycles: a critical review. *J Adolesc Health Care*. 1982;2:249–60
19. Crawford JD, Osler DC. Body composition at menarche: the Frisch-Revelle hypothesis revisited. *Pediatrics*. 1975;56:449–458
20. Guo SS, Chumlea WC, Roche AF, et al. Age- and maturity-related changes in body composition during adolescence into adulthood: the Fels Longitudinal Study. *Int J Obes*. 1997;21:1167–1175
21. Troiano RP, Flegal KM. Overweight children and adolescents: description, epidemiology, and demographics. *Pediatrics*. 1998;101:497–504
22. Troiano RP, Flegal KM, Kuczmarski RJ, et al. Overweight prevalence and trends for children and adolescents: the National Health and Nutrition Examination Surveys, 1963 to 1991. *Arch Pediatr Adolesc Med*. 1995;149:1085–1091
23. Tanner JM. Growth at Adolescence: With a General Consideration of the Effects of Hereditary and Environmental Factors Upon Growth and Maturation from Birth to Maturity. 2nd ed. Oxford, United Kingdom: Blackwell Scientific Publishers; 1962
24. Frisch RE, Mearthar JW. Menstrual cycles: fatness as a determinant of minimum weight for height necessary for their maintenance or onset. *Science*. 1974;185:949–951
25. National Center for Health Statistics. Plan and operation of the Third National Health and Nutrition Examination Survey, 1988–94; 1994. Report No.: Vital Health Statistics 1(32).
26. National Center for Health Statistics. Plan and operation of a health examination survey of U.S. youths 12–17 years of age. Washington: Public Health Service; 1969 September. Report No.: Vital and Health Statistics: PHS Pub. No. 1000-Series 1-No. 8
27. National Center for Health Statistics. Plan, operation, and response results of a program of children's examinations. Washington: Public Health Service; 1967 Oct. 1967. Report No.: Vital and Health Statistics: PHS Pub. No. 1000-Series 1-No. 5
28. Ogden CL, Kuczmarski RL, Flegal KM, et al. 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
29. Himes JH, Dietz WH. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. *Am J Clin Nutr*. 1994;59:307–316
30. Centers for Disease Control and Prevention. Defining Overweight and Obesity. <http://www.cdc.gov/nccdphp/dnpa/obesity/defining.htm>. Accessed September 13, 2002.
31. Mohadjer L, Montaquila J, Waksberg J, et al. National Health and Nutrition Examination Survey III: Weighting and estimation methodology: Executive summary. Rockville, MD: Westat, Inc: prepared for National Center for Health Statistics; 1996 February
32. Finney DJ. Probit Analysis. Cambridge, United Kingdom: Cambridge University Press; 1964
33. Wang YH. Fiducial intervals: what are they? *Am Stat*. 2000;54:105–111
34. Brogan DJ. Software for sample survey data, misuse of standard packages. In: Armitage P, Colton T, eds. *Encyclopedia of Biostatistics*. New York, NY: John Wiley and Sons; 1998:4167–4174
35. Lee PA, Kulin HE, Guo SS. Age of puberty among girls and the diagnosis of precocious puberty. *Pediatrics*. 2001;107:1493
36. Hewlett PS, Plackett RL. *The Interpretation of Quantal Responses in Biology*. Baltimore, MD: University Park Press; 1979
37. Morrison JA, Barton BA, Biro FM, et al. Sexual maturation and obesity in 9- and 10-year-old black and white girls: the NHLBI growth and health study. *J Pediatr*. 1994;124:889–895
38. Garn SM, Lavelle M, Pilkington JJ. Comparison of fatness in premenarcheal and postmenarcheal girls of the same age. *J Pediatr*. 1983;103:328–331
39. Adair LS, Gordon-Larsen P. Maturation timing and overweight prevalence in US adolescent girls. *Am J Public Health*. 2001;91:642–644
40. Colon I, Caro D, Bourdony CJ, et al. Identification of phthalate esters in the serum of young Puerto Rican girls with premature breast development. *Environ. Health Perspect*. 2000;108:895–900
41. Su-Ting TL, Lozano P. Hormone-containing hair product use in prepubertal children. *Arch Pediatr Adolesc Med*. 2002;156:85–86
42. Blanck HM, Marcus M, Tolbert PE, et al. Age at menarche and tanner stage in girls exposed in utero to polybrominated biphenyl. *Epidemiology*. 2000;11:641–647
43. Persson I, Ahlsson F, Ewald U, et al. Influence of perinatal factors on the onset of puberty in boys and girls: implications for interpretation of link with risk of long term diseases. *Am J Epidemiol*. 1999;150:747–755
44. Ellis BJ, Garber J. Psychosocial antecedents of variation in girls' pubertal timing: maternal depression, stepfather presence, and marital and family stress. *Child Dev*. 2000;71:485–501
45. Wierson M, Long PJ, Forehand RL. Toward a new understanding of early menarche: the role of environmental stress in pubertal timing. *Adolescence*. 1993;28:913–925

Relative Weight and Race Influence Average Age at Menarche: Results From Two Nationally Representative Surveys of US Girls Studied 25 Years Apart

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