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Feature Article

Recent Decline in Age at Menarche: The Fels Longitudinal Study

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ABSTRACT A number of recent reports suggest that the average age at menarche of US girls has declined over the past 20 years. Because the putative declines in the age at menarche are concurrent with increases in childhood body mass index (BMI), it has been suggested that these two trends may be causally linked. We examined differences in mean age of menarche in Fels Longitudinal Study girls who were born in six 10-year birth cohorts (1930s, 1940s, 1950s, 1960s, 1970s, and 1980s) and simultaneous cohort changes in mean BMI measured cross-sectionally at selected ages from 3–35 years (n = 371). Girls born in the 1980s had a mean age at menarche of 12.34 years, which was ~3–6 months earlier than that of girls born previously ($P < 0.001$). While the mean BMI values at ages 25 and 35 generally increased from the 1930s to the 1970s, the mean BMI during childhood and adolescence remained constant across the six birth cohorts. In summary, we found no evidence that the recent decline in the age at menarche in the Fels Longitudinal Study girls was reflected in concurrent increases in BMI at any point in childhood or adolescence. Conversely, girls born in the 1960s and 1970s have subsequently become heavier in young and mid-adulthood than were girls from earlier birth cohorts, without any concurrent change in the mean age at menarche over that time period. These two findings suggest that population-level shifts in BMI and the timing of menarche are largely independent, although sometimes coincident, processes. Am. J. Hum. Biol. 16:453–457, 2004.

A number of recent reports suggest that the average age at menarche of U.S. girls has declined over the past 20 years. In the Bogalusa Heart Study, a significant decline in the mean age at menarche was found between 1978–1979 and 1992–1994 in both African American girls (a 10-month drop) and white girls (a 2-month drop) (Wattigney et al., 1999; Freedman et al., 2002). A small, 2–3 month decrease in the median age at menarche, from ~12.75 years to 12.5 years, has been documented in nationally representative samples of U.S. girls seen between the NHES (National Health Examination Survey, conducted 1963–1966) and the NHANES III (third National Health and Nutrition Examination Survey, conducted 1988–1994) (Anderson et al., 2003; Chumlea et al., 2003). It has also been suggested that the incidence of early puberty increased in U.S. girls in the 1990s (Herman-Giddens et al., 1997; Kaplowitz et al., 2001), although a recent comparison of national survey data from NHES to NHANES III does not indicate a trend toward early sexual maturation (breast, genitalia, pubic hair development) in US children (Sun et al., 2003). Nonetheless, because the putative declines in the age at menarche are concurrent with increases in childhood body mass index (BMI) (Ogden et al., 2002; Troiano et al., 1995), it has been suggested that these two trends are causally linked. Body weight and body fatness have been highlighted as possible causal determinants of the age at menarche most notably by the work of Frisch and colleagues (e.g., Frisch and Revelle, 1970; Frisch and McArthur, 1974).

The aims of the present analysis are to examine the mean age of menarche in successive birth cohorts of girls in the Fels Longitudinal Study (born from 1929 to 1990), and to examine simultaneous cohort changes in mean BMI measured from age 3–35 years. These data afford an opportunity to view trends in menarcheal timing and BMI that predate the initiation of national health and nutrition surveys in the US.

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SUBJECTS AND METHODS

Age at menarche data were available from 371 white females in the Fels Longitudinal Study, the largest and longest-running study of growth, development, and later disease risks in the world (Roche, 1992). Individuals were born between 1929 and 1990. Children in the Fels Longitudinal Study are scheduled for visits every 6 months from 2–18 years of age. At each of these semiannual visits, females age 9 years and older responded to questions regarding whether or not they started menstruating since their last visit. If the answer is yes, the girls are then asked to provide, if possible, an exact date. In most cases, girls report the onset of their menses at their first study examination after menarche. Eighty percent reported menarche within 6 months of its onset, and the remaining 20% reported menarche within 5 years of its onset, which limits the likelihood of recall error. The BMI was calculated in kg/m^2 using standard procedures for the measurement of height and weight (Lohman et al., 1988).

To quantify the linear trend in the age at menarche over time, the correlation coefficient between age at menarche and year of birth was calculated. To examine possible birth cohort differences in the mean age at menarche, analysis of variance (ANOVA) was used to compare mean age at menarche across six decades of birth, defined as follows: Cohort 1, born 1929–1939 (n = 59); Cohort 2, born 1940–1949 (n = 42); Cohort 3, born 1950–1959 (n = 72); Cohort 4, born 1960–1969 (n = 72); Cohort 5, born 1970–1979 (n = 55); and Cohort 6, born 1980–1990 (n = 71). Similarly, we used an ANOVA to assess birth cohort differences in the mean BMI at particular chronological ages (ages 3, 6, 9, 15, 18, 25, and 35, and at the age closest to menarche for each girl—which was within 1 year of menarche) to examine the simultaneity of changes in the age at menarche and childhood and adulthood BMI. SAS v. 8.02 was used for all analyses (SAS Institute, Cary, NC) and statistical significance was defined at $P < 0.05$.

RESULTS

The correlation between age at menarche and birth year was small but significant and in the hypothesized direction ($r = -0.14$, $P = 0.008$). To explore this secular trend further, the study sample was divided into six birth cohorts according to year of birth, as described above. Figure 1 shows that the mean age at menarche is very similar for girls born in the 1930s, 1940s, 1950s, and 1960s (12.72–12.99 years). Girls born in the 1970s had a slightly lower mean age at menarche of 12.58 years (although this is not significantly different from girls born in previous decades), and girls born in the 1980s had a mean age at menarche of 12.34 years (significantly lower than girls born in the 1930s, 1940, 1950s, or 1960s, $P < 0.001$). Overall, decade of birth explained 5% of the variance in age at menarche in this study sample.

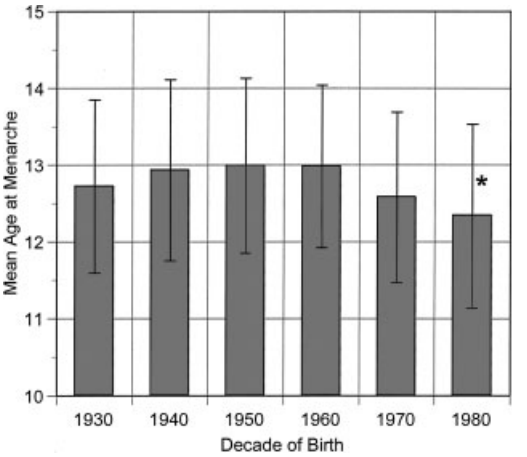

Fig. 1. Mean age at menarche (±SD) in 371 Fels Longitudinal Study girls, by decade of birth. An asterisk indicates mean age at menarche is significantly different from the reference group (1930 birth decade).

To examine trends in age-specific BMI simultaneous with the decline in the age at menarche, we tested the hypothesis that the mean BMI at particular chronological ages increased over time (Table 1). While the mean BMI values at ages 25 and 35 generally increased from the 1930s to the 1960s or 1970s, the mean BMI during childhood and adolescence (i.e., at 3, 6, 9, age at menarche, 15, and 18 years of age) remained constant across the six birth cohorts. These data are shown graphically in Figure 2 and demonstrate how secular increases in female BMI emerged during the middle of the 20th century, but only among young adult women. The small decline in the age at menarche observed in girls from the most recent birth cohort (born 1980–1990) was not accompanied by a concurrent increase in childhood BMI.

TABLE 1. Trends in age-specific BMI (mean ± SD) by decade of birth

Age (years)	1930	1940	1950	1960	1970	1980	*P*
3	15.7 ± 0.9	15.7 ± 1.1	16.1 ± 1.3	15.8 ± 1.3	15.4 ± 1.1	15.4 ± 1.1	ns
6	15.2 ± 1.2	15.2 ± 1.6	15.5 ± 1.5	15.4 ± 1.5	15.5 ± 1.1	15.3 ± 2.0	ns
9	16.7 ± 1.9	16.3 ± 2.6	16.7 ± 2.3	16.7 ± 2.3	17.4 ± 2.3	17.0 ± 3.0	ns
Menarche	18.2 ± 3.2	18.2 ± 2.9	19.0 ± 3.5	18.8 ± 2.9	19.1 ± 3.1	19.4 ± 3.5	ns
15	20.2 ± 3.5	19.9 ± 2.2	20.8 ± 2.9	21.4 ± 3.1	21.1 ± 3.0	22.0 ± 3.4	ns
18	21.0 ± 3.6	21.3 ± 4.3	21.5 ± 2.6	22.4 ± 3.4	21.9 ± 2.8	21.9 ± 3.3	ns
25	20.4 ± 2.4	21.8 ± 4.7	22.3 ± 3.7	23.7 ± 5.4	23.7 ± 4.3	n.a.	0.002
35	21.9 ± 3.5	23.3 ± 4.9	25.2 ± 4.8	25.8 ± 6.6	n.a.	n.a.	0.002

n.a., Girls born in the 1970s have not yet been followed to age 35, and girls born in the 1980s have not yet been followed to age 25 for the estimation of their mean BMI at those ages.

DISCUSSION

In this generally healthy southwestern Ohio population there is overall evidence of a modest secular trend for earlier age at menarche during the latter part of the 20th century. When the data were examined by birth cohort, it was apparent that this decline was not gradual across the period of investigation, but rather was restricted to a relatively recent 3–6 month drop in the mean age at menarche in girls born in the 1970s and 1980s as compared to girls born earlier in the century. Our results are generally in accordance with recent reports of a decline of ~3 months in white girls in the Bogalusa Heart Study (Freedman et al., 2002), and a 2–3 month decline in the median age at menarche in US girls over the 25-year period between the NHES and the NHANES III (Anderson et al., 2003). Not all studies have found a secular decline in the age at menarche, however. No such trend was found in white girls in the Pediatric Research in Office Settings study (who were born between ~1980–1990) compared to white girls measured during the NHES (born in the 1950s) (Herman-Giddens et al., 1997). Furthermore, the reported decline in the median age at menarche in US girls between NHES (cycles 2 and 3) and NHANES III (Anderson et al., 2003) was not considered significant in a similar analysis (Chumlea et al., 2003) in which the results from NHANES III were compared with the published median age at menarche from NHES (cycle 3 only; MacMahon, 1973). The mean age at menarche in Fels Longitudinal Study girls born 1929–1969 was the same as the US national median age for non-Hispanic white girls from the NHES (i.e., 12.8 years) (MacMahon, 1973). Likewise,

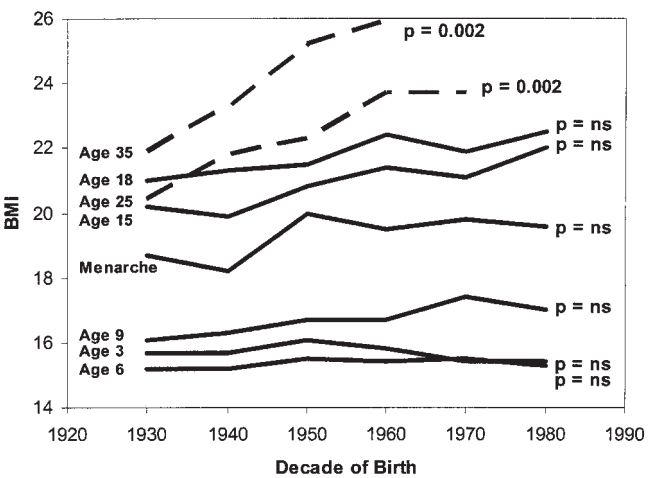

Fig. 2. Trends in age-specific BMI in 371 Fels Longitudinal Study girls, by decade of birth.

the mean age at menarche in Fels girls born 1970–1979 (12.58 years) was similar to the US national median age for white girls interviewed as part of the NHANES III (median = 12.55 years) (Chumlea et al., 2003). The Fels Longitudinal Study girls, therefore, have been generally representative of the greater US population of white girls in regard to sexual maturation.

It is unclear at this time whether or not the recent downward shifts in the mean age at menarche seen in this and other studies are biologically meaningful. Compared to marked decreases in the average age at menarche during the Industrial Revolution in Europe (Tanner, 1962) and during the more recent nutritional transitions seen elsewhere (Graham et al., 1999; Kac and Velasquez-Melendez, 2000; Pasquet et al., 1999), the recent secular decline in the mean age at menarche in US girls, where it has been observed, is relatively small in magnitude.

We found no evidence that the recent decline in the age at menarche in the Fels Longitudinal Study girls was reflected in concurrent increases in BMI at any point in childhood or adolescence. Conversely, girls born in the 1960s and 1970s have subsequently become heavier in young and mid-adulthood than were girls from earlier birth cohorts, without any concurrent change in the mean age at menarche over that time period. We have as yet too little long-term follow-up data on girls born in the 1980s to make inferences regarding their BMI in adulthood. However, these cross-sectional data point to increasing BMI and decreasing age at menarche as largely independent processes in this population. A limitation of our study is that data on body composition is lacking for girls born during the early phases of the study. In the Fels Longitudinal Study population, the correlation between BMI and percent body fat from underwater weighing is rather modest in children ($r = 0.55$ in boys and $r = 0.58$ in girls less than 18 years of age), but is more robust in adults ($r = 0.77$ in males and females greater than 18 years of age). Because BMI is an imprecise indicator of adiposity, particularly in children, our inability to find a relationship between mean age at menarche and mean BMI during childhood may stem from the fact that the timing of menarche is more closely linked to changes in body composition than to changes in BMI during the period of growth and development.

In conclusion, in this healthy white population followed for over 60 years, mean age at menarche declined by ~6 months in girls born 1980–1990 compared to girls born 1930–1979, but there was no concurrent increase in BMI during childhood or adolescence in that group compared to earlier birth cohorts. Although we did detect a secular increase in BMI among young adult women born during the period 1930–1970, the mean age at menarche remained stable during that period. These two findings suggest that population-level shifts in BMI and the timing of menarche are largely independent, although sometimes coincident, processes.

LITERATURE CITED

Anderson S, Dallal G, Must A. 2003. Relative weight and race influence average age at menarche: results from two nationally representative surveys of US girls studied 25 years apart. Pediatrics 111:844–850.

Chumlea W, Schubert C, Roche A, Kulin H, Lee P, Himes J, Sun S. 2003. Age at menarche and racial comparisons in US girls. Pediatrics 111:110–113.

Freedman D, Kahn L, Serdula M, Dietz W, Srinivasan S, Berenson G. 2002. Relation of age at menarche to race, time period, and anthropometric dimensions: the Bogalusa Heart Study. Pediatrics 110:e43.

Frisch RE, McArthur JW. 1974. Menstrual cycles: fatness as a determinant of minimum weight for height necessary for their maintenance or onset. Science 185: 949–951.

Frisch RE, Revelle R. 1970. Height and weight at menarche and a hypothesis of critical body weights and adolescent events. Science 169:397–399.

Graham MJ, Larsen U, Xu X. 1999. Secular trend in age at menarche in China: a case study of two rural counties in Anhui Province. J Biosoc Sci 31:257–267.

Herman-Giddens M, Slora E, Wasserman R, Bourdony C, Bhapker M, Koch G. 1997. Secondary sex characteristics and menses in young girls seen in office practice: a study from the Pediatric Research in Office Settings Network. Pediatrics 99:505–512.

Kac G, Velasquez-Melendez G. 2000. Secular trend in age at menarche for women born between 1920 and 1979 in Rio de Janeiro, Brazil. Ann Hum Biol 27: 423–428.

Kaplowitz P, Slora E, Wasserman R, Pedlow S, Herman-Giddens M. 2001. Earlier onset of puberty in girls: relation to increased body mass index and race. Pediatrics 108:347–353.

Lohman T, Roche A, Martorell R. 1988. Anthropometric standardization reference manual. Champaign, IL: Human Kinetics.

MacMahon B. 1973. Age at menarche, United States. Washington, DC: National Center for Health Statistics, Vital and Health Statistics. Series 11. Report No. 133NCHS. DHEW Publ. No. (HRA) 74–1615.

Ogden C, Flegal K, Carroll M, Johnson C. 2002. Prevalence and trends in overweight among US children and adolescents, 1999–2000. JAMA 288:1728–1732.

Pasquet P, Biyong A, Rikong-Adie H, Befidi-Mengue R, Garba M, Froment A. 1999. Age at menarche and urbanization in Cameroon: current status and secular trends. Ann Hum Biol 26:89–97.

Roche AF. 1992. Growth, maturation and body composition: the Fels Longitudinal Study 1929–1991. Cambridge, UK: Cambridge University Press.

Sun SS, Schubert CM, Liang R, Roche AF, Kulin HE, Lee PA, Himes JH, Chumlea WC. 2003. Is sexual maturity occurring earlier among U.S. children? Pediatr Res 54(5):777.

Tanner J. 1962. Growth at adolescence. London: Blackwell Scientific.

Troiano RP, Flegal KM, Kuczmarski RJ, Campbell SM, Johnson CL. 1995. Overweight prevalence and trends for children and adolescents: The National Health and Nutrition Examination Surveys, 1963–1991. Arch Pediatr Adolesc Med 149:1085–1091.

Wattigney W, Srinivasan S, Chen W, Greenlund K, Berenson G. 1999. Secular trend of earlier onset of menarche with increasing obesity in black and white girls: the Bogalusa Heart Study. Ethn Dis 9:181–189.