The Menstrual Cycle and Adolescent Health

Susannah Heyer Barsom,[a] Heather E. Dillaway,[b] Patricia Barthalow Koch,[a] Mona L. Ostrowski,[c] and Phyllis Kernoff Mansfield[d]

[a]*Department of Biobehavioral Health, The Pennsylvania State University, University Park, Pennsylvania, USA*

[b]*Department of Sociology, Wayne State University, Detroit, Michigan, USA*

[c]*Population Research Institute, The Pennsylvania State University, University Park, Pennsylvania, USA*

[d]*Department of Women's Studies, The Pennsylvania State University, University Park, USA*

Early reproductive characteristics, including menarcheal age, may have significant effects on later health outcomes. While early exposure to ovarian hormones may influence the risk for certain diseases, the degree to which this exposure is mediated by other factors is not well understood. Research on secular trends in age at menarche and subsequent outcomes in women's health across the lifespan can help to clarify the importance of age at menarche. Since 1934, the TREMIN Research Program on Women's Health has collected longitudinal data on menstruation and reproductive health. Recently we examined the age at menarche across the entire population of TREMIN participants, across the two major cohorts of this research program (participants initially enrolled in the 1930s and in the 1960s), and within families where mothers and daughters participated in the study. Our results indicated that age at menarche among the 4,444 mainly European American girls in our sample decreased in the first part of the twentieth century, and then began to increase in the late 1940s. The comparison of age at menarche across the two major cohorts reinforced this analysis: age at menarche was slightly but significantly lower ($P < .001$) in the second cohort (12.66), most of whom were born in the 1940s, than in the first cohort (12.89), those women born before 1920. In analyzing data from 380 mother–daughter pairs, there was no significant difference between mothers' and daughters' mean age at menarche and no significant correlation between them.

Key words: **menarche; menstruation; secular trend; adolescence**

Introduction

The TREMIN Research Program on Women's Health, begun in 1934, is one of the oldest ongoing longitudinal studies of menstruation and reproductive health. Over the last seven decades, TREMIN has enrolled several thousand U.S. women into its longitudinal study.[1] The 2,350 women recruited in the 1930s, primarily as undergraduate students at the University of Minnesota, comprise Cohort One. Another 1,600 women recruited in the 1960s, also at the University of Minnesota, make up Cohort Two, which was intended to provide a comparison group to the first cohort. Daughters of participants have been invited into the study, resulting in 555 mother–daughter families. From 1966 to 1971, a group of approximately 3,000 women living in Alaska, both indigenous and Caucasian, joined the study (many of them very briefly). In 1990 the last panel entered the study; a group of midlife women, all graduates of Douglass College in New Jersey, was recruited to be part of a special midlife study of health, along with long-time TREMIN participants of similar age. With the exception of the native Alaskans, the group has always been predominantly European American, reflecting the makeup of the university community from which most of the participants were recruited. While this lack of diversity can be viewed as a problematic issue, in that TREMIN is not a nationally representative sample, it can sometimes be seen as advantageous because for many purposes, the group can be treated as a homogeneous population.

Women in the TREMIN program have prospectively recorded menstrual bleeding and have completed a general health report form annually.[1] The

Address for correspondence: Susannah Heyer Barsom, Department of Biobehavioral Health, 315 Health and Human Development, East, The Pennsylvania State University, University Park, PA 16802. Voice: 814-863-7256; fax: 814-863-7525.

shb2@psu.edu

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questions included on the health report form have varied over the years and women have remained in the study for widely varying lengths of time, making it difficult to conduct analyses on the entire group of TREMIN participants. One item that has regularly been recorded, however, is age at menarche. Although there are missing data, and variability in recall (some women enrolled in the study at menarche, but most of them enrolled years later), these data can be examined to determine general trends in age at menarche.

Secular Trend in Age at Menarche and Its Importance in Health

Scholars have generally accepted that age at menarche has been decreasing in Western or developed countries. Okasha *et al.*[2] suggest that results from Western countries show a decrease in age at menarche over generations of women born prior to 1940. Yet from studies of cohorts born after or around 1940, reports on this secular trend are more varied. Brudevoll *et al.*[3] report no changes in menarcheal age after this year. Roberts and Dann[4] report increases in age at menarche after this time, and a somewhat curvilinear trend between 1934 and 1959, characterized by both decreases and increases during that time. Hauspie *et al.*[5] report decreases only. And while Okasha *et al.*[2] find an overall decrease in age at menarche in women born between 1920 and 1952, they do not find a constant decrease over this 30-year period. Instead, they report increases in age at menarche for women born in the early 1920s, late 1920s, and mid-1930s. Likewise, in a French study of 86,031 women born between 1925 and 1950, Clavel-Chapelon *et al.*[6] report that in at least two different cohorts there were reported increases in the age at menarche. Specifically, women born between 1925 and 1930 and women born in 1946 and1947 had increased menarcheal ages compared to the cohorts before them. Nichols *et al.*[7] also report that in a U.S.-based cohort study of 22,774 women, those participants who were born between 1960 and 1969 had an increased average menarcheal age. They conclude that while there is a general trend toward decreasing age at menarche for those born between 1910 and 1949, there is in fact a U-shaped overall trend between the years of 1910 and 1969.[7] Many studies now indicate that the downward trend has stopped and perhaps even reversed slightly, as younger cohorts have reported slightly increased ages at menarche.[6–9]

Methods

Because the TREMIN participants were recruited into the study in several different groups, and over such a long period of time, they can be categorized in a number of different ways. We looked at age at menarche across the two main cohorts, across the entire participant pool, and among mothers and daughters.

Information on age at menarche was not available for all women who had participated in the TREMIN Research Program. In some cases the information appears never to have been recorded; in others, it is probable that the data were lost. (Given the study's long history, the changes in technology over that time, and the changes in the housing of the project,[1] a loss of some data seems inevitable.)

Age at Menarche in Cohort One and Cohort Two

According to Mansfield and Bracken,[1] the idea behind recruiting a second cohort was to determine the nature of any secular trends in menstrual cycle characteristics. In keeping with that intent, we first examine the average age at menarche for the two cohorts, using a two-tailed *t*-test to compare the means. After excluding participants for whom we had no age at menarche, we were able to compare age at menarche for 1,932 Cohort One women with age at menarche for 843 Cohort Two women.

Age at Menarche across All TREMIN Participants

Because the remaining data on age at menarche provides information from over eight decades, we have examined the entire TREMIN cohort as a single group. Again, pertinent information was not available for all TREMIN participants, but data on age at menarche were available for 4,444 women born between 1893 and 1991. We provide simple summary statistics, and graphically display the data by birth cohort.

Age at Menarche in Mothers and Daughters

We examined age at menarche in mothers and daughters enrolled in the TREMIN study. Again, for the reasons mentioned above, age at menarche was not available for all mother–daughter pairs. In the majority of the mother–daughter pairs (73%), the mother was born between 1906 and 1920; the remainder of the mothers' births were spread across the thirty-year period from 1921 to 1950. For the purpose of examining the relationship between mothers' and daughters' ages at menarche, we treated the older group of mothers as a single cohort and analyzed only their data and that of their daughters. In the cases where a mother had more than one daughter in the study, the menarcheal age of only one of the daughters, selected at random, was used

TABLE 1. Average age at menarche across two cohorts[a]

	Cohort One	Cohort Two
Mean[b]	12.89	12.66
Standard deviation	1.32	1.32
Number of subjects	1932	843

[a]Cohort One was recruited in 1930s,Cohort Two in 1960s.
[b]Statistically significant difference ($P < .001$).

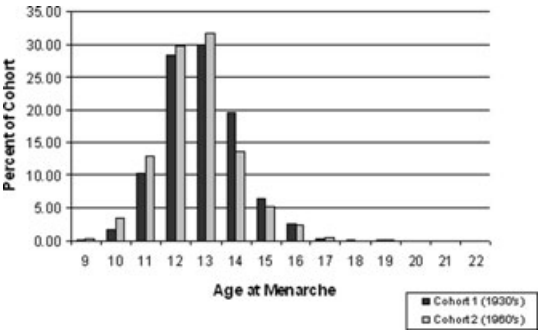

FIGURE 1. Distribution of age at menarche in two cohorts.

in the analysis. On the resulting 380 mother–daughter pairs, paired *t*-tests and correlation analyses were used to investigate the relationship between mothers' and daughters' ages at menarche.

Results

Age at Menarche in Cohort One Compared to Cohort Two

In comparing the women of the first cohort with those recruited roughly 30 years later, we found a somewhat small, but significant ($P < .001$) difference in age at menarche. TABLE 1 compares the mean and standard deviations for Cohort One and Cohort Two, whose average ages at menarche were 12.89 years of age and 12.66 years of age, respectively.

We can further examine the differences by graphing the distribution of ages at menarche in these two groups (FIG. 1). The overall distribution curve is similar, but the first cohort has a somewhat higher percentage of individuals reaching menarche at older ages.

Age at Menarche across the TREMIN Population

Average age at menarche for the 4,444 women for whom age at menarche was available was 12.78 (SD = 1.36). In order to examine any trends in age at menarche, we examined the data by birth cohort, in this case by decade of birth (TABLE 2). Because the number of participants born in the 1890s ($n = 17$), 1980s ($n = 26$) and 1990s ($n = 2$) was too small, these decades were not included in the graphical display ($n = 4{,}399$).

TABLE 2. Age at menarche by decade of birth

Decade of Birth	Mean Age at Menarche	SD	*n*
1890 (1893)–1899	*14.35*	*2.03*	*17*[a]
1900–1909	13.48	1.54	137
1910–1919	12.85	1.28	1761
1920–1929	12.54	1.24	223
1930–1939	12.45	1.34	361
1940–1949	12.65	1.39	1318
1950–1959	12.75	1.40	256
1960–1969	13.37	1.36	193
1970–1979	12.83	1.24	150
1980–1989 (1988)	*12.62*	*1.33*	*26*[a]
1990–1991	*13*	*0*	*2*[a]

[a]Not included in graph.

FIGURE 2 indicates that the average age at menarche for TREMIN participants across eight decades first decreases to a low of 12.45 for the cohort born in the 1930s, then increases generally until another apparent decrease for the cohort born in the 1970s. The general shape of this trend is similar to that described by Nichols *et al.*,[7] though the timing of the shifts in trends are not the same. The one-way ANOVA indicated that age at menarche differed significantly as a function of decade of birth ($F(7, 4390) = 17.37$, $P < .001$)

Age at Menarche in Mothers and Daughters

Using a paired *t*-test, we compared mean age at menarche in 381 mother–daughter pairs, and found no significant difference between the groups: the mothers had a mean age at menarche of 12.82 (SD = 1.22) and the daughters had a mean age at menarche of 12.80 (SD = 1.38). Further, no significant correlation between the mothers' and daughters' age at menarche was found; in view of a correlation coefficient of 0.03 ($P > .05$), we can report only that there is a non-significant, near-zero positive correlation between the mothers' and daughters' age at menarche (FIG. 3).

Discussion

Overall our findings support much of the existing research on age at menarche in Western

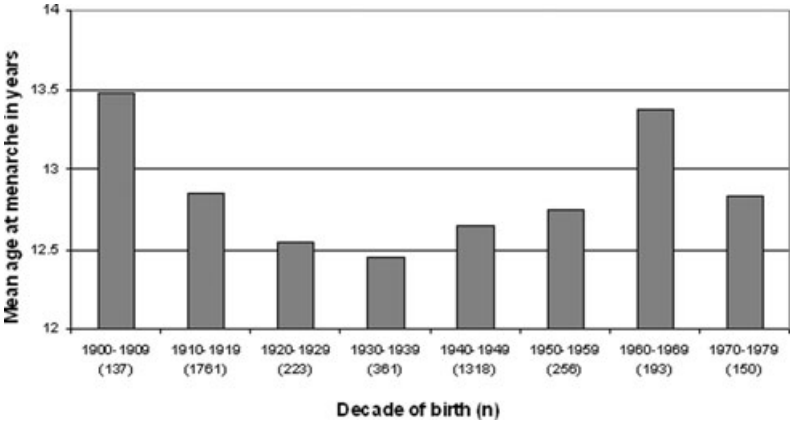

FIGURE 2. Mean age at menarche by birth cohort ($F(7, 4390) = 17.37$, $P < .001$).

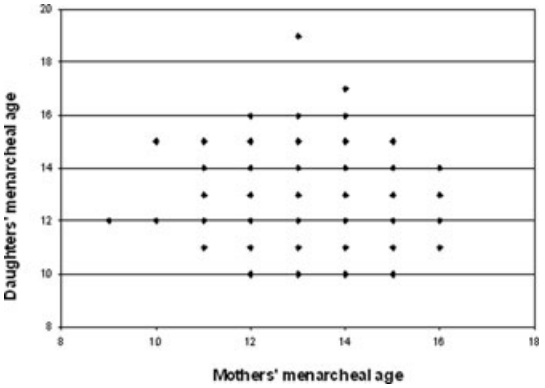

FIGURE 3. Scatter plot of mothers' versus daughters' menarcheal ages ($r = 0.03$; $P > .05$).

populations. The downward trend across the two main TREMIN cohorts was not surprising, given the previously reported secular trend for the time periods in question. That these results support other findings is particularly important because of the fact that the TREMIN information on age at menarche was reported either at the time of menarche or, in most cases, at least within 10 years of menarche, while many of the other studies are retrospective. (Although the sample size of TREMIN participants born in the 1980s was small, it is intriguing that the data suggest that another downward trend in menarcheal age may be occurring.)

Trends in age at menarche are difficult to interpret, even when obvious changes in potentially important environmental variables are simultaneously observed. The trend toward a decrease in menarcheal age has been attributed to a number of different factors, including climate changes (such as changes in the amount of sunshine), the eradication of some chronic diseases, improved nutrition, and genetic factors.[6] It has been suggested that slight increases in menarcheal ages may be related to unhealthy diets (particularly among certain populations by race/ethnicity or social class), stress, and even psychological factors.[6] While the stress of an impending World War II was considered important in the observed increase in age at menarche seen in some pre-war European cohorts, the increases seen in more recent cohorts are sometimes attributed to diet and exercise patterns brought on by a culture of thinness.[6] At the same time, Nichols *et al.*[7] suggest that improved nutritional status may be a reason for decreases in menarcheal ages among some younger cohorts. Other studies have suggested that age at menarche is influenced by factors such as adverse environmental conditions in early life,[2,9] social class,[2,3] race, childhood weight status/BMI, and nutritional intake,[7,10,11] socioeconomic status of parents,[10] and number of siblings.[12] The degree to which these social factors influence age at menarche is difficult to estimate, and studies report mixed results on their importance. The consensus that scholars seem to have reached is that increased weight and high BMI in children are associated with a decreased age at menarche in the overall population.[10] Studies also continue to indicate that social class—and at the very least, low social class—is often associated, even if indirectly, with a decreased age at menarche.[10]

There is a body of literature that suggests that early reproductive characteristics, for instance, menarcheal age, can have a significant impact on later female health.[13] That is, women's health and illness as adults may be influenced by their age at first menstruation.

Studies on this topic have examined how early menarche may be associated with an increased risk of breast cancer,[2,6,11,13,14] endometrial cancer,[13] and obesity[2,15] later in life. Using the TREMIN database, Cooper *et al.*[16] found a decreased risk of heart disease associated with women who experience menarche at later ages. It has been suggested that early exposure to endogenous ovarian hormones and the presence of higher estrogen concentrations in the body over time may influence the risk of certain diseases;[6,7] however, the existence of confounding and mediating factors complicates the interpretation of menarcheal data. For instance, Maclure *et al.*[11] suggest that increased risk of breast cancer may be explained partially by greater nutritional intake and changing diet over a lifetime, factors which have also been associated with both early and late menarche. One study based in Scotland and a second study in northern Finland found that high BMI and obesity in adult life is associated with early menarche,[10,12] though this relationship is confounded by high childhood BMI, high BMI during adolescence, and low social class of the child's family. Nichols *et al.*[7] have suggested that late menarche translates into increased risk for bone fracture and osteoporosis later in life.

More research is indeed needed, not only on the secular trends in age at menarche but also its effects on women's health over a lifetime. In conducting such research in the future, careful consideration should be given to the distinction between menarche and the onset of regular (ovulatory) cycling,[6] and the fact that age at menarche may be of less significance than the onset of ovulatory cycling in adolescence.

The U-shaped curve representing the age at menarche for the entire cohort, while not precisely replicating the findings from other populations, does support a similar reversal of the previous downward trend in age at menarche, as reported by several investigators.[6–9] Although the TREMIN participants have generally been from well-educated middle-class families, the database does not have detailed indicators of socioeconomic status that might suggest reasons for the observed changes in the average age at menarche.

One potentially confounding factor is the fact that many of the women in the study are related to one another. In conducting analyses on the entire group, we have always been mindful of the possibility of genetic relatedness influencing our outcomes. The fact that a comparison of mothers' and daughters' age at menarche indicated that there is almost no correlation between the two suggests that genetic relatedness may be less of a problem in analyzing age at menarche than it would be for other biological factors.

Conclusions

As mentioned in the introduction, there has been some investigation into the TREMIN data on age at menarche and later health outcomes.[16] Work to date has primarily dealt with the first cohort. The many years' worth of data both on the second cohort and on the daughters, particularly those who enrolled in the study at or shortly after menarche, provide a strong basis on which to investigate relationships between menarche, early cycle characteristics, and eventual health outcomes.

Conflicts of Interest

The authors declare no conflicts of interest.

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