

# AGE AT MENARCHE\*

## Genetic and Environmental Influences

LEONA ZACHARIAS, PH.D., AND RICHARD J. WURTMAN, M.D.

CLINICIANS are often asked by concerned parents whether their daughter's age at menarche is abnormally late — or abnormally early. In answer, it may be said that what is normal for a particular girl depends upon her genes and life history as well as the common characteristic of human females to start to menstruate at sometime during the second decade of life.

For each species of mammal, a characteristic period elapses between birth and the development of full sexual function. In normal girls evidence of sexual maturation characteristically appears not at four or 40, but at eight or 10 or 12 years of age. At that time, most healthy girls begin to have physical manifestations of the changes in ovarian function that are associated with reproductive maturity. Their breasts start to bud, and hair appears in the pubic and axillary regions. Within a year, the first episode of menstrual bleeding occurs, providing clear evidence that the ovary is now capable of secreting significant quantities of steroid hormones. Sometime thereafter, the brain begins to emit cyclic neuroendocrine signals at intervals of approximately 29 days; these signals cause the pituitary gland to release the hormones responsible for ovulation, and the reproductive capability of a woman is thereby established.

Very little is known at present about why the process of maturation starts when it does and then proceeds at its specific pace. Experimental studies may eventually clarify the processes responsible for sexual maturation. However, until such knowledge is available, clinicians and other students of human biology must use information derived from the techniques of the study of natural history to determine the extent to which an individual girl's sexual maturation depends upon her genes, her health and her environment. This report attempts to summarize the available information concerning the factors that cause menarche to occur when it does.

For more than a century, and in many parts of the world, studies have been made on the course of human sexual development and its relation to the

individual's biologic status and environment. From these investigations it has become clear that the data obtained by examination of one population are rarely applicable to another, or even to the same society a decade later. Hence, to define the relation between a particular genetic or environmental factor and sexual development, comparisons should be limited to groups maturing at approximately the same time and living under similar conditions.

In studying variations in the rate of sexual development, most investigators have attempted to relate these changes to one particular factor affecting the populations under study (such as climate, altitude, season, nutrition, hygiene, disease, psychologic stimulation, urban vs rural living, race or physical habitus). Many of these factors are in fact inter-related, and their effects on maturation cannot be examined separately. For example, the ability of environmental and social influences to over-ride genetic influences is illustrated by Ito's<sup>1</sup> observation that Japanese girls born and reared in California reached menarche more than a year and a half earlier than those born in California but reared in Japan, or those born and reared in Japan [R].†

In the following discussion, certain factors influencing menarche have, for practical reasons, been considered individually. Since this is unrealistic, we have attempted to point out inter-relations where relevant.

### FACTORS THAT MAY INFLUENCE SEXUAL DEVELOPMENT

#### Geography

Geography, in the sense in which it is used here, involves not only physical locus but also the whole relation between the human being and his environment. In the investigation of the influence of the geography of a specific region on the sexual maturation of its inhabitants, it is important to distinguish between the effects of actual geographic factors (that is, latitude, longitude, altitude, characteristic temperature, humidity and lighting) and those of the socioeconomic results of these circumstances.

*Temperature and humidity.* Recent research has not supported the belief, once widely held, that sexual development occurs at an earlier age in the tropics than in temperate zones. In fact, there is

†"R" designates a *retrospective* study, in which girls or women were questioned about their age at menarche sometime *after* the event had occurred.

\*From the Vincent Memorial Hospital, Gynecology Service of the Massachusetts General Hospital, Boston, and the Department of Nutrition and Food Science, Massachusetts Institute of Technology, Cambridge (address reprint requests to Dr. Zacharias at the Vincent Memorial Hospital, Massachusetts General Hospital, Fruit St., Boston, Mass. 02114).

Supported by grants (H.D. 01582 and AM-11709) from the United States Public Health Service and by a grant (NGR-22-009-272) from the National Aeronautics and Space Administration.

now almost unanimous agreement that climate in itself has little or no effect on menarche. Kennedy<sup>2</sup> reported that menarche occurs at the same age in Edinburgh, Rome and South Russia, places in which both temperature and humidity differ markedly [R]. The mean menarcheal age of  $14.22 \pm 1.00^*$  years [R] reported by Ellis<sup>3</sup> for girls in Lagos, Nigeria, differs very little from that specified in Levine's<sup>4</sup> study of Alaskan Eskimos ( $14.42 \pm 1.20$  years) [SQ].† Israel<sup>5</sup> noted that the mean menarcheal age in Indian women ( $13.59 \pm 1.48$  years) [R] was not significantly different from that reported for European and American women. Wilson and Sutherland<sup>6</sup> found similar mean menarcheal ages in the hot, humid areas of Central India ( $14.65 \pm 1.55$  years) and the hot, dry regions of Northern Nigeria ( $14.65 \pm 1.24$  years) [SQ]. Foll<sup>7</sup> too reported almost identical menarcheal ages in Chauk, Burma (very hot and dry), and Digboi, Upper Assam (very hot but moist) [SQ].

Some studies suggest that menarche may actually be delayed in the tropics. Mills<sup>8</sup> suggested that the climate of the stormy temperate zone accelerates growth and sexual development, whereas that of moist, humid areas retards maturation [R]. Wilson and Sutherland<sup>6</sup> compared the mean age of menarche in urban Ceylon ( $12.84 \pm 1.24$  years), rural Ceylon ( $14.39 \pm 1.73$  years) and the south of England ( $13.49 \pm 1.19$  years) and concluded that the age at menarche is not determined by climate.

**Altitude.** Valšik et al.<sup>9</sup> reported that elevation above sea level influences menarcheal age at the rate of approximately three months' delay for each 100 meters of altitude. They studied the sexual maturation of daughters of farming families residing at different altitudes in the mountains of northwest Slovakia and found that girls living at the highest altitudes had a significantly later menarche (14.9 years) than those living at the lowest elevations (14.2 years) [R]. As the authors pointed out, the economic and nutritional conditions at high altitudes are poorer, and the caloric requirements for existence may be greater.

**Light.** The possibility that light influences human sexual maturation has not received much attention. Zacharias and Wurtman<sup>10</sup> compared two populations of blind girls (one born prematurely and the other at full-term) with two comparable nonblind groups and found that in both groups of blind girls, the age at menarche was lower than that in the nonblind groups. When blindness was compounded by a total loss of light perception, menarche occurred even earlier [R].

**Season.** Few studies have been made of the relation between season and the advent of menarche, and the findings have not been consistent.

In 1923 Bolk<sup>11</sup> obtained data on menarche from

2000 Dutch girls, and found that the highest monthly incidence of menarche (10.3 per cent) occurred between May and August; another smaller peak (8.5 per cent per month) occurred in December and January; very few girls started to menstruate in February or October [R]. Zacharias, Wurtman and Schatzoff<sup>12</sup> made similar observations on 6217 American nursing students [R]. Reymert and Jost<sup>13</sup> studied 261 girls residing in a settlement in Mooseheart, Illinois; they too observed that menarche was more likely to occur in summer or winter than in fall or spring [P].‡

On the other hand, Matsumoto et al.<sup>14</sup> found that among 10,000 Japanese girls, the incidence of menarche was greatest in the spring and summer and lower in the fall and winter [R]. Engle and Shelesnyak,<sup>15</sup> in their study of 250 girls in a New York City orphanage, found that the incidence of menarche was fairly constant during autumn (25 per cent), winter (30 per cent), and spring (25 per cent) but dropped to 18 per cent in the summer [P].

If menarche does indeed occur more frequently in one time of the year than another, it is possible that the effect of season is mediated by the annual cycle of changing length of day. There is ample evidence<sup>16</sup> that the annual onset of gonadal activation is controlled in this manner in most monestrous mammals (that is, animals that ovulate once a year). One might anticipate that if this effect operated in human beings, seasonal changes in the incidence of menarche would be more marked in populations living at some distance from the equator. In such regions, one might also expect to find related seasonal variations in the incidence of pregnancy.

#### Month of Birth

In a study of 50,000 South African Bantu school-girls (10 to 18 years of age) living in the Transkei Reserve, Burrell et al.<sup>17</sup> observed a relation between month of birth and age at menarche. Girls born early in the year menstruated four months earlier, on the average, than those born at the end of the year [SQ]. This correlation, which might actually arise from seasonal variations in the adequacy of nutrition, is discussed below.

#### Socioeconomic Factors

Studies performed in many regions of the world have shown that an acceleration of physical growth and sexual maturation follows a major improvement in socioeconomic conditions. In fact, Fluhmann<sup>18</sup> suggested that the average age at menarche might be taken as an index of the general well-being of a people.

Socioeconomic level is compounded of many factors, such as nutrition, public and individual health,

\*Standard deviation, unless otherwise noted.

†"SQ" designates a status quo study, in which each girl was asked her age and whether she had already experienced menarche.

‡"P" designates a prospective or longitudinal study, in which girls who had not yet started to menstruate were questioned, at suitable intervals over a long time, concerning the age at occurrence of the first menstrual period.

family size and urban vs rural living. It will be apparent from the following discussion that the inter-relation of these factors precludes the evaluation of their individual contributions.

**Nutritional and economic factors.** Stratz<sup>19</sup> reported strikingly different mean ages at menarche among Bavarian girls of different economic levels: 12.9 years for the upper class; 14.4 for the middle class; and 16.4 for peasants [R]. Michelson,<sup>20</sup> in comparing the influence of racial characteristics, climate and socioeconomic factors on puberty, reported that both Southern-born and Northern-born American Negroes matured earlier when reared in the North rather than in the South of the United States, and that in the West Indies, puberty occurred even later than in the South [R]. Among the populations studied, nutrition was reported to be poorer in the South than in the North, and worst in the West Indies. Michelson also found that the age at maturity was similar among whites and Negroes belonging to similar income groups ( $12.85 \pm 1.14$  years for Negroes and  $12.86 \pm 1.04$  for whites), and that the Negro population as a whole had a later onset of puberty ( $13.09 \pm 1.12$  years) than the white population ( $12.86 \pm 1.04$  years), possibly because of the lower standard of living among the Negroes. He concluded that the economically privileged groups mature earlier than the underprivileged, regardless of race or climate.

Kark<sup>21</sup> studied four groups of South African Bantu girls (total of 1088) of the same ethnic origin but living in widely different environments. She found that the girls in the more southern, temperate climate had better physiques, less evidence of malnutrition or specific disease and earlier menarche (by at least one year) than those living in the hotter northern area, where bilharzia, malaria and malnutrition were prevalent [SQ]. Young et al.<sup>22</sup> noted a marked lowering of menarcheal age in 31 Florentine families who had moved upward in the socioeconomic scale (in terms of the father's education and occupation, and the condition of the home), during a 30-year period [R and P].

Kiil<sup>23</sup> reported that the Lapps, who maintained intact their pastoral nomadic life, showed no change in mean age at menarche (16.5 years) between 1870 and 1930, whereas during the same period, the mean menarcheal age declined by almost two years among their farming Norwegian neighbors [R].

A few investigators have attempted to identify the components of the diet that might be responsible for the menarcheal acceleration associated with improved socioeconomic status. Burrell et al.,<sup>17</sup> in their 1961 study of Bantu girls (mentioned above), found that girls classified by the school authorities as "poor" had a mean menarcheal age of  $15.42 (\pm 0.04 \text{ S.E.})$  years whereas those designated as "not poor" (on the basis of a larger intake of animal protein) experienced menarche at  $15.02 (\pm 0.05 \text{ S.E.})$  years. They also reported a tendency for girls born early in the calendar year to begin menstruation

four months earlier than those born at the end of the year, and suggested that this correlation might have a nutritional basis, since a shortage of *amasi* (fermented milk) occurs regularly in June and July, and a shortage of grain sometimes appears in August and September.

Kralj-Čerček<sup>24</sup> studied the sexual development of 148 Slovenian girls and observed that for those whose diet was rich in protein, the mean age at menarche was  $12.65 (\pm 0.13 \text{ S.E.})$  years whereas for girls whose diet was largely carbohydrate, it was  $14.1 (\pm 0.11 \text{ S.E.})$  years [R].

Prosperi et al.,<sup>25</sup> studying 2256 girls and women in Tuscany, found that girls who had been breast-fed reached menarche earlier (12.6 years) than those who had been bottle-fed (13.6 years) [R].

Whatever the explanation, the accelerating influence of good nutrition on puberty has been reported from many parts of the world (for example, in Denmark,<sup>26</sup> China,<sup>27</sup> Japan,<sup>14</sup> Mexico<sup>28</sup> and Israel<sup>29</sup>). An effect probably related to temporary nutritional deprivation was described by Ellis,<sup>30</sup> who investigated the growth and development of 106 adolescent Belgian girls living in working-class communes during World War II. He observed that the nutritional deprivation of the war and enemy occupation was associated with delayed menarche in a significant proportion of these girls [SQ]. Keys et al.<sup>31</sup> compiled a large series of reports supporting the hypothesis that puberty is delayed in periods of severe food shortage.

Backman<sup>32</sup> made an extensive review of the time scale of human development in Europe during the last 500 years and pointed out that there has been a recent tendency in Europe toward equalization of the onset of puberty [R]. Similarly, Richter,<sup>33</sup> in the study mentioned above, investigated menarche ages in a German industrial town during the period 1944 to 1949 and reported that the acceleration in maturation among the upper social groups was leveling off [R]. The differences between the more and less prosperous families found in 1944 was much less evident in 1949, probably because of a marked rise in standard of living for the poorer groups. Prosperi et al.<sup>25</sup> reported that whereas in the prewar period (1930-1943), working girls in Tuscany had matured one year later than students, no such class differences were found among girls born during the postwar period (1944-1945) [R]. In recent Scottish<sup>34</sup> and English<sup>35</sup> studies, no significant difference in menarcheal age among girls of different economic strata is reported. Apparently, poverty or malnutrition can delay sexual development, but improvement in living standards beyond a certain level does not continue to accelerate the process.

**Family size.** Scott<sup>36</sup> reported that among low-income groups in London, the age at menarche is delayed in families with many siblings [SQ]. Valšik et al.<sup>9</sup> observed that menarcheal age was 14.3 years in Czech families with one or two children, and 14.6 years in those with six or more siblings [R].

This phenomenon might be explained on the basis of substandard nutrition in large, low-income families.

*Urban vs rural environment.* Whether because of better nutrition, improved hygiene, increased social or sexual stimulation, some genetic factor that instigates migration to cities or other unidentified influences, residence in a town appears to predispose to early sexual maturation. This phenomenon has been observed in many parts of the world and over a long period. As early as 1610, Quarinonius<sup>37</sup> noted that Austrian peasant girls menstruated much later than the daughters of the townsfolk or the aristocracy. Wilson and Sutherland<sup>38</sup> reported that the mean age at menarche for girls in urban Ceylon was 12.84 ( $\pm 1.24$ ) years whereas in rural areas it was 14.39 ( $\pm 1.73$ ) years [SQ]. In southern India, Madhavan<sup>39</sup> found that urban girls matured earlier than rural girls (12.76 years for urban and 14.16 years for rural) [SQ].

*Psychologic factors.* The study of the effect of psychologic and emotional factors on menarcheal age is complicated by the fact that emotional disturbances are often the result of conditions that themselves exercise an influence on sexual development. For example, the emotional stresses associated with deprivation may contribute to the difference in menarcheal age between well-off and impoverished populations.

The possibility that the earlier menarcheal age of town dwellers is caused by increased social stimulation has been mentioned above. However, Romanus<sup>40</sup> found that girls in a coeducational school in Uppsala did not experience menarche earlier than pupils in an all-girls school [R]. As for the possible psychologic effect of institutional living on menarche, Engle and Shelesnyak<sup>15</sup> found no correlation between age at menarche and the duration of residence in an orphanage [P].

Wilson and Sutherland<sup>41</sup> investigated the relation between participation in tribal initiation rites (including female circumcision) and menarcheal age among 162 girls in Sierra Leone. This painful ritual (practiced by the Mende and Temne tribes, but not by the Creoles) is of high emotional content, since it signifies a girl's readiness for marriage. The investigators reported no correlation between participation in these initiation rites and the age at menarche. For tribal girls it was 13.44 ( $\pm 1.30$ ) years, and for Creoles, it was 13.65 ( $\pm 0.94$ ) years [SQ].

Reymert<sup>42</sup> found that the age at menarche was in no way related to the degree of intelligence. In a study of 138 girls, the distribution of the I.Q. was the same among those having early (11 to 13 years) or late (14 to 16 years) menarche. In addition, no differences in mean age at menarche were noted between a group of 28 girls with behavior disorders and a group of 46 with records of normal behavior [P].

## Diseases

Only a few reports have been published concerning the possible effects of pathologic states on menarcheal age.

Arduino and Ferreira,<sup>43</sup> in a study of 422 diabetic girls and 455 normal girls in Brazil, reported that menarche occurred earlier (by about one year) in the former [R]. Post<sup>44</sup> observed a similar correlation in a group of 166 diabetic women (with postadolescent diagnoses) and 91 normal controls: the mean menarcheal age was 12.77 ( $\pm 1.49$ ) years for the diabetic and 13.55 ( $\pm 1.51$ ) years for the nondiabetic women [R]. White<sup>45</sup> studied 222 female 30-year survivors of juvenile diabetes, and found that menarche occurred early in prediabetic girls whose disease became evident after the age of 18, and late when the diabetes appeared before 11 years of age [R].

The effects of blindness on menarche<sup>10</sup> were discussed in the first section of this report.

Obesity has been found to be associated with precocious menarche.<sup>22,46-48</sup> The menarcheal acceleration appears to be in proportion to the degree of obesity, although this correlation does not hold for girls more than 30 per cent over maximum expected weight for their height and somatotype.<sup>12</sup> Beyond this level, girls tend to experience delayed menarche.

## Genetic Control of Sexual Development

The influence of genetic factors may be considered in the larger context of racial characteristics or in the more immediate aspect of family heredity.

*Race.* It is virtually impossible to isolate the effects of racial factors on sexual development. In the first place, very few populations exist that are racially pure; most commonly, many constitutional types are present in each person. Secondly, racial factors, like climate, cannot be separated from socioeconomic influences such as habitat and nutrition.

Robertson,<sup>49</sup> in 1851, wrote:

The black peasant females of the West Indies, and the manufacturing females of Manchester [England] arrive at puberty about the same period of life, namely, soon after completion of the fifteenth year. The more opulent classes of society menstruate at a somewhat earlier age, on the average; which is to be ascribed to no natural difference, but to circumstances.

Studies of peoples of very different racial and ethnic characteristics (such as American Negroes,<sup>20</sup> tropical Africans,<sup>3</sup> Japanese,<sup>1</sup> Oriental and Yemenite Israelis<sup>50</sup> and Alaskan Eskimos<sup>4</sup>) have demonstrated that although hereditary influences exist, they are far outweighed by environmental circumstances, regardless of race.

*Family heredity.* Mothers and daughters. Unless data for both mothers and daughters are obtained prospectively (and we have been unable to find any such study), comparison of their menarcheal ages is complicated by the fact that the data on the two generations are not really comparable. Either the data for the daughters are prospective, whereas

those for the mothers are retrospective, or, if both sets are retrospective, the daughters' accounts of the recent events of menarche are likely to be more accurate than the mothers' recollections of the much more distant event.<sup>3,21,26,42,51</sup>

A few reports indicate that there is a fairly good correlation between the menarche ages of mothers and their daughters. Bolk<sup>11</sup> studied 45 mothers and their 71 daughters and reported that among mothers with menarcheal ages of 11 to 13 years, the daughters' average age at menarche was 12 years and 10 months; among mothers whose menses started at 14 to 16 years, the daughters' average age at onset was 13 years and seven months; and among women whose menstruation started at 17 to 19 years, their daughters experienced menarche at 14 years and 11 months [R]. Popenoe,<sup>52</sup> in a study of 200 mothers and their 351 daughters, found a correlation coefficient of  $0.40 \pm 0.03$  between mothers' and daughters' menarcheal ages [R].

Sisters. Although it would be easier to demonstrate the genetic influence on sexual development by study of twins and sisters, only a few such studies have been reported. Petri<sup>53</sup> noted a difference in menarcheal age of two and eight-tenths months in a group of 51 pairs of identical twins, 12.0 months in a group of 47 pairs of nonidentical twins, 12.9 months in a group of 145 pairs of sisters and 18.6 months in 120 pairs of unrelated women [R]. Reymert and Jost<sup>13</sup> found a significantly smaller difference in menarcheal age between 72 pairs of sisters than between 200 pairs of unrelated girls. The mean difference for the group of sisters was 10.6 months; for the unrelated groups it was 13.9 months [P]. Tisserand-Perrier,<sup>54</sup> in France, found a difference in menarche age of eight and two-tenths months in a group of 39 fraternal twins and two and two-tenths months in a group of 46 identical twins [P].

*Age at menarche and body growth and configuration.* Although there have been numerous studies of the relation between body configuration and the timing of sexual maturation, their findings are not always in agreement.

On the one hand Barker and Stone,<sup>55</sup> in California, noted that "... women with late menarcheal ages tend towards the longitudinal (leptosomic) type, whereas those with early menarcheal ages tend towards the lateral (pyknic) type" [R]. Kralj-Čerček,<sup>24</sup> in Yugoslavia, reported that menarcheal age for "Baroque" women (broad and feminine) was 12.93 years, for "Renaissance" (medium) it was 13.5 years and for "Gothic" (linear and boyish) it was 14.61 years [R]. McNeill and Livson,<sup>48</sup> in California, found that girls who mature early are less slender at menarche than those who mature late, owing, they thought, to differences in body build that are present from childhood, rather than to differential growth during adolescence [P]. Young et al.,<sup>22</sup> in Florence, Italy, reported that girls with early menarche are fatter and less linear than others [R and P]. Tanner<sup>56</sup> summarizes these findings as follows:

"... in countries where nutrition may be more than adequate, fatness and early-maturing go together. Linear people, both men and women, develop later."

On the other hand, there are many reports indicating that early menarcheal age is associated with generally advanced body growth and development rather than with body type or height-weight ratio. Simmons and Greulich<sup>57</sup> reported that girls with early menarche are advanced in mean skeletal age over girls with late menarche [R]. Jokl<sup>58</sup> studied a group of 40 13-year-old white girls in South Africa and found that those who had started to menstruate were taller, heavier and bulkier than those who had not [SQ]. Hogben et al.<sup>59</sup> concluded, from a study of 662 English girls in primary and secondary schools, that above-average weight and above-average height tend to be associated with early puberty [P]. Mukherji and Sengupta<sup>60</sup> studied the school health records of 691 Indian schoolgirls nine to 17 years old, and found that in each group those who had experienced menarche were taller and heavier than those who had not [R].

#### LOWERING OF MENARCHEAL AGE DURING THE PAST CENTURY

There is considerable evidence that in Western Europe and the United States, there has been an acceleration of sexual development during the past 100 years. This trend is regarded as one aspect of a general acceleration of human growth. As Tanner<sup>56</sup> has stated: "Age at menarche has been getting earlier by some 4 months per decade in Western Europe over the period 1830-1960." The acceleration might be the result of unrelated processes that have affected specific communities at specific times (for example, technologic and agricultural advances, improvements in dietary and public-health practices and urbanization). If so, the lowering of menarcheal age would not necessarily be continuous or general, but would parallel the environmental changes. On the other hand, if a universal biologic process were acting on *all* girls to accelerate sexual maturation, the downward trend would be uninterrupted and worldwide.

Studies of menarcheal acceleration have been of two sorts: those investigating the phenomenon over a relatively short time by comparing the menarcheal ages of mothers and their daughters; and those recording the general downward trend of maturational age in large populations over a long period. In both types of reports, it has been almost impossible to separate the effect of the passage of time per se from the multiple effects of concomitant socioeconomic changes. (For this reason, we have avoided using the term "secular trend" to describe the decline in menarcheal age, since this designation might imply that the passage of time alone has been the cause.)

There are many reports<sup>11,52,61</sup> that girls have an earlier onset of menstruation than their mothers, but very few in which it is clear that no major nutrition-

al or socioeconomic advances occurred during the 20 or 30 years under consideration. Actually, most studies involved populations that have clearly been influenced by technologic advances. When investigation is made of peoples who have not so benefited, no acceleration of development is observed. For example, Kiil<sup>23</sup> (as mentioned above) reported that the nomadic Lapps had the same mean menarcheal age (16½ years) between 1870 and 1930. Israel<sup>5</sup> found no significant difference in menarcheal ages between mothers and daughters in a population of Indian women who had experienced no improvement in diet.

It is absurd to suggest that the advent of menarche has occurred earlier and earlier without interruption, for century upon century no matter what the starting point. Although the keeping of reliable health records is relatively recent, it is possible to estimate the age at menarche during certain periods in the past by examining the writings of those periods. For example, in the fifth and sixth centuries in Rome, where a boy or girl was considered to have attained majority when he or she became capable of reproduction, the Byzantine emperor Justinian, in his *Corpus Juris Civilis* (528-534), fixed the age of legal majority at 14 years for boys and at 12 years for girls. Similarly, a thousand years later, the Council of Trent (1545-1563) set the earliest legal age for marriage at 14 years for boys and 12 years for girls.

In 1610, Quarinonius,<sup>37</sup> in Austria, stated:

The peasant girls of this landschaft in general menstruate much later than the daughters of the townfolk or the aristocracy, and seldom before their seventeenth, eighteenth or even twentieth year . . . The townfolk have usually born several children before the peasant girls have yet menstruated. The cause seems to be that the inhabitants of the town consume more fat food and drink and so their bodies become soft, weak and fat and come early to menstruation. . . .

Thus, Quarinonius not only observed that the onset of menstruation occurred earlier in town dwellers,

TABLE 1. Mean Menarcheal Ages in the United States as Reported in Prospective Studies,\* 1934-1966.

Yr	AGE AT MENARCHE (Yr)		No. OF SUBJECTS	POPULATION STUDIED
	MEAN ± SD	RANGE		
1934	13.53	11.04-16.31	250	Residents of Hebrew Orphan Asylum, New York, N.Y. <sup>15</sup>
1937	13.1 ± 1.1		248	Members of Harvard Growth Study <sup>46</sup>
1940	13.1	11.2-15.7	138	Residents of Mooseheart, Illinois (settlement for families of deceased members of Loyal Order of Moose) <sup>12</sup>
1948	12.9 ± 1.4		32	Members of Fels Research Institute for Study of Human Development, Antioch, O. <sup>62</sup>
1953	12.8 ± 1.1		91	Members of Guidance Study, Institute of Child Welfare, Berkeley, Cal. <sup>63</sup>
1962	12.8 ± 1.1		43	Members of Guidance Study, Institute of Child Welfare, Berkeley, Cal. <sup>51</sup>
1966	12.60 ± 2.0		262	American schoolgirls residing in Rio de Janeiro, Brazil, & in Midwest of United States <sup>64</sup>

\*Those in which girls who had not yet started to menstruate were questioned at intervals concerning age at which 1st menstrual period occurred.

in the privileged and in the obese, but also gave figures for menarcheal age in Austria in the early seventeenth century (18 to 20 years for peasants and 14 years or less for town dwellers and the rich). Similar information for sixteenth-century London may be found in the plays of Shakespeare.

To explain the fluctuations in the age at menarche with time, Fluhmann<sup>18</sup> proposed "... the possibility that there is a uniform, relatively early prototype for the menarcheal age which applies to the whole human race and which becomes delayed as the result of adverse external circumstances." Backman<sup>32</sup> suggested that the variations in menarcheal age

TABLE 2. Mean Menarcheal Ages in the United States as Reported in Retrospective Studies,\* 1932-1964.

Yr	AGE AT MENARCHE (Yr)		No. OF SUBJECTS	POPULATION STUDIED
	MEAN ± SD	STANDARD ERROR		
1944†	14.3	—	—	Residents of Colored Orphan Asylum, Riverdale, N.Y. <sup>20</sup>
1932	13.5 ± 1.1	—	185	Residents of Hebrew Orphan Asylum in New York
	13.1 ± 1.2	—	352	Students of Horace Mann School (private) in New York, N.Y. <sup>65</sup>
1944‡	13.07 ± 1.1	—	113	Residents of Colored Orphan Asylum, Riverdale, N.Y. <sup>20</sup>
1943	12.6 ± 1.1	—	200	Participants in Brush Foundation Regular Series, Cleveland, O. <sup>57</sup>
1962§	13.17	±0.03	—	Students at Wellesley College, Wellesley, Mass. <sup>44</sup>
1964	12.46 ± 0.85	—	236	Nursing students in Greater Boston, Mass. <sup>10</sup>
1968	12.65 ± 1.2	—	6217	American student nurses in all parts of United States <sup>12</sup>

\*Those in which women are questioned about their age at menarche after the event.

†Data obtained in 1910-1914.

‡Data obtained in 1935-1940.

§Data obtained in 1958.

TABLE 3. Mean Menarcheal Ages in Great Britain, 1948-1961.

Yr	AGE AT MENARCHE (Yr)		NO. OF SUBJECTS	POPULATION STUDIED	TYPE OF STUDY*
	MEAN $\pm$ SD	STANDARD ERROR			
1960†	13.38	$\pm 0.05$	1,151	Day-school students (not rich) in Dorset, England	SQ
	13.11	$\pm 0.09$	202	Boarding-school students (rich) in Sussex, England <sup>61</sup>	
1950	13.73 $\pm$ 1.37	—	470	Nursing students in England <sup>3</sup>	R + SQ
1956	13.32 $\pm$ 1.53	—	516	Blood donors, <25 yr of age in Oxford, England <sup>66</sup>	R
1960‡	13.03	$\pm 0.06$	1,029	Day-school students (not rich) in Sussex, England	SQ
	13.30	$\pm 0.18$	283	Boarding-school students (rich) in Sussex, England <sup>61</sup>	
1961	13.06	$\pm 0.02$		Middle-class schoolgirls in London, England <sup>36</sup>	SQ

\*R indicates retrospective, SQ status quo (studies in which each girl is asked her age & whether she has already experienced menarche).

†Data obtained in 1948-49.

‡Data obtained in 1957.

among European girls between 1800 and 1943 paralleled the fluctuations in industrial activity — for example, that the war of 1870 and the ensuing revolutionary movements had exercised a retarding influence on sexual development in France.

A comparison of menarche ages reported during the last 40 years, from many regions of the world, shows no overall secular trend. If, however, data from same studies are analyzed according to country, it is clear that the menarcheal age has become lower in certain places but not in others. For example, prospective studies<sup>15,42,46,51,62-64</sup> (Table 1) conducted in the United States between 1934 and 1966 show that there has been a drop of 10 to 12 months (about three and six-tenths months per decade) in menarcheal age during this period. Retrospective studies<sup>10,12,20,44,57,65</sup> (Table 2) show a somewhat steeper rate of decline (four and four-tenths months per decade). However, very little trend is demonstrated by English studies<sup>3,36,61,66</sup> (Table 3) made between 1948 and 1961. For most of the other European countries (such as northern Europe,<sup>26,67</sup> middle Europe<sup>9,24,68</sup> and Italy<sup>22,25</sup>) there are not enough comparable studies made over a sufficiently long period to show a clear change with time. This is also true for equatorial Africa,<sup>41</sup> Alaska,<sup>4</sup> Brazil,<sup>43</sup> China,<sup>27</sup> India,<sup>39</sup> Israel,<sup>50</sup> Jamaica,<sup>69</sup> Japan<sup>14</sup> and Mexico.<sup>28</sup>

In summary, the age at onset of menstruation is not fixed, but varies from population to population, and changes with time. Although it is to some extent influenced by family heredity, body build, photic input and season, it seems more susceptible to modification by certain socioeconomic influences (such as nutrition and urban vs rural living) and by specific disorders (for example, diabetes, obesity and blindness).

We are indebted to Dr. Howard Ulfelder for advice and encouragement and to Misses Scobie Evans and Barbara Gale for secretarial and research assistance.

## REFERENCES

- Ito, P. K. Comparative biometrical study of physique of Japanese women born and reared under different environments. *Human Biol.* 14:279-351, 1942.
- Kennedy, W. Menarche and menstrual type: notes on 10,000 case records. *J. Obst. & Gynaec. Brit. Emp.* 40:792-804, 1933.
- Ellis, R. W. B. Age of puberty in tropics. *Brit. M. J.* 1:85-89, 1950.
- Levine, V. E. Studies in physiological anthropology. III. Age of onset of menstruation of Alaska Eskimos. *Am. J. Phys. Anthropol.* 11:252, 1953.
- Israel, S. Onset of menstruation in Indian women. *J. Obst. & Gynaec. Brit. Emp.* 66:311-316, 1959.
- Wilson, D. C., and Sutherland, I. Age of menarche in tropics. *Brit. M. J.* 2:607, 1953.
- Foll, C. V. Age at menarche in Assam and Burma. *Arch. Dis. Childhood* 36:302-304, 1961.
- Mills, C. A. Geographic and time variations in body growth and age at menarche. *Human Biol.* 9:43-56, 1937.
- Valšik, J. A., Štukovský, R., and Bernátová, L. Quelques facteurs géographiques et sociaux ayant une influence sur l'âge de la puberté. *Biotypol.* 24:109-123, 1963.
- Zacharias, L., and Wurtman, R. J. Blindness: its relation to age at menarche. *Science* 144:1154, 1964.
- Bolk, L. Menarche in Dutch women and its precipitated appearance in youngest generation. *Proc. Acad. Sc. Amsterdam Sec. Sc.* 26:650-663, 1923.
- Zacharias, L., Wurtman, R. J., and Schatzoff, M. Unpublished data.
- Reymert, M. L., and Jost, H. Further data concerning normal variability of menstrual cycle during adolescence and factors associated with age of menarche. *Child Development* 18:169-179, 1947.
- Matsumoto, S., Ozawa, M., Nogami, Y., and Ohashi, H. Menstrual cycle in puberty. *Gunma J. Med. Sc.* 12:119-143, 1963.
- Engle, E. T., and Shelesnyak, M. C. First menstruation and subsequent menstrual cycles of pubertal girls. *Human Biol.* 6:431-453, 1934.
- Wurtman, R. J. Effects of light and visual stimuli on endocrine function. In *Neuroendocrinology*. Edited by L. Martini and W. F. Ganong. New York: Academic Press, 1967. Pp. 19-59.
- Burrell, R. J. W., Healy, M. J. R., and Tanner, J. M. Age at menarche in South African Bantu schoolgirls living in Transkei reserve. *Human Biol.* 33:250-261, 1961.
- Fluhmann, C. F. Menstrual problems of adolescence. *Pediatr. Clin. North America* 5:51-62, 1958.
- Stratz, C. H. *Der Körper des Kindes und seine Pflege*. Ninth edition. Stuttgart: Ferdinand Enke, 1922.
- Michelson, N. Studies in physical development of Negroes. IV. Onset of puberty. *Am. J. Phys. Anthropol.* 2:151-166, 1944.
- Kark, E. Menarche in South African Bantu girls. *South African J. Med. Sc.* 8:35-40, 1943.
- Young, H. B., Zoli, A., and Gallagher, J. R. Events of puberty in 111 Florentine girls. *Am. J. Dis. Child.* 106:568-577, 1963.
- Kiil, V. Stature and growth of Norwegian men during past 200 years. *Skr. norske Vidensk. Akad.* 6:175, 1939.
- Kralj-Čerček, L. Influence of food, body build, and social origin on age at menarche. *Human Biol.* 28:393-406, 1956.
- Prosperi, P., Borselli, L., and Matucci-Cerinic, L. Indagine statistica sul più precoce sviluppo sessuale delle ragazze in Toscana. *Riv. di clin. pediat.* 74:28-45, 1965.
- Bojlén, K., Rasch, G., and Weis Bentzon, M. Age incidence of menarche in Copenhagen. *Acta obst. et gynec. Scandinav.* 33:405-433, 1954.
- Lee, M. M. C., Chang, K. S. F., and Chan, M. M. C. Sexual maturation of Chinese girls in Hong Kong. *Pediatrics* 32:389-398, 1963.
- Ramos-Galvan, R., Mariscal, C., and Viniestra, A. Menarche and nutrition (preliminary report). *Bol. méd. Hosp. infant. Méx.* 7:169-180, 1963.

29. Guggenheim, K., Abramson, J. H., Perez, E., and Reshef, A. Diet and nutrition of children in selected Jerusalem schools. *Israel J. Med. Sc.* 2:344-349, 1966.
30. Ellis, R. W. B. Growth and health of Belgian children: during and after German occupation (1940-1944). *Arch. Dis. Childhood* 20: 97-109, 1945.
31. Keys, A., Brožek, J., Henschell, A., Mickelsen, O., and Taylor, H. L. Sexual function. In *The Biology of Human Starvation*. Minneapolis: Minnesota Press, 1950. Pp. 749-763.
32. Backman, G. Die beschleunigte Entwicklung der Jugend: verfrühte Menarche, verspätete Menopause, verlängerte Lebensdauer. *Acta Anat.* 4:421-480, 1948.
33. Richter, J. Das gegenwärtige Menarchealter in Görlitz. *Arztl. Jugendkunde* 55:393-398, 1964.
34. Nisbet, J. D., and Illesly, R. I. Influence of early puberty on test performance at age eleven. *Brit. J. Educ. Psychol.* 33: 169-176, 1963.
35. Douglas, J. W. B. *The Home and the School: A study of ability and attainment in the primary school*. London: MacGibbon and Kee, 1964.
36. Scott, J. A. *Report on the Heights and Weights (and Other Measurements) of School Pupils in the County of London in 1959*. London: County Council, 1961.
37. Quarinius, H. *Die Grewel der Verwürlung menschlichen Geschlechts*. Innsbruck, 1610.
38. Wilson, D. C., and Sutherland, I. Age at menarche. *Brit. M. J.* 1: 1267, 1950.
39. Madhavan, S. Age at menarche of South Indian girls belonging to states of Madras and Kerala. *Indian J. M. Research* 53:669-673, 1965.
40. Romanus, T. Menarche in schoolgirls: effects of joint and of separate education. *Acta genet.* 3:50-60, 1952.
41. Wilson, D. C., and Sutherland, I. Female circumcision and age at menarche. *Brit. M. J.* 1:1375, 1955.
42. Reymert, M. L. Relationships between menarcheal age, behavior disorders, and intelligence. *Character & Personality* 8:292-300, 1940.
43. Arduino, F., and Ferreira, F. da C. A menarca e a menopausa na mulher diabética e pré-diabética. *Arq. brasil Endocrinol.* 7:77-85, 1958.
44. Post, R. H. Early menarcheal age of diabetic women. *Diabetes* 11:287-290, 1962.
45. White, P. Childhood diabetes: its course, and influence on second and third generations. *Diabetes* 9:345-355, 1960.
46. Shuttleworth, F. K. Sexual maturation and physical growth of girls age six to nineteen. *Mongr. Soc. Research Child Develop.* 2 (No. 5): P 253, 1937.
47. Wolff, O. H. Obesity in childhood: study of birth weight, height, and onset of puberty. *Quart. J. Med.* 24:109-123, 1955.
48. McNeill, D., and Livson, N. Maturation rate and body build in women. *Child Develop.* 34:25-32, 1963.
49. Robertson, J. *Essays and notes on physiology and diseases of women*. London, 1851.
50. Sohar, E., and Rieber, E. Age of menarche in girls of various Jewish communities in Israel. *Harefuah* 59:303-305, 1960.
51. Livson, N., and McNeill, D. Accuracy of recalled age of menarche. *Human Biol.* 34:218-221, 1962.
52. Popenoe, P. Inheritance of age of onset of menstruation. *Eugenics News* 13:101, 1928.
53. Petri, E. Untersuchungen zur Erbbedingtheit der Menarche. *Ztschr. f. Morphol. Anthropol.* 33:43-48, 1935.
54. Tisserand-Perrier, M. Etude comparative de certains processus de croissance chez les jumeaux. *J. génét. humaine* 2:87-102, 1953.
55. Barker, R. G., and Stone, C. P. Physical development in relation to menarcheal age in university women. *Human Biol.* 8:198-222, 1936.
56. Tanner, J. M. *Growth at Adolescence: With a general consideration of the effects of hereditary and environmental factors upon growth and maturation from birth to maturity*. Second edition. Oxford: Blackwell Scientific Pub., 1962. P. 152.
57. Simmons, K., and Greulich, W. W. Menarcheal age and height, weight and skeletal age of girls age 7 to 17 years. *J. Pediat.* 22: 518-548, 1943.
58. Jokl, E. Menarche, growth and physical efficiency. *Nature (London)* 157:195, 1946.
59. Hogben, H., Waterhouse, J. A. H., and Hogben, L. Studies on puberty: Part I. *Brit. J. Soc. Med.* 2:29-42, 1948.
60. Mukherji, P. S., and Sengupta, S. K. Menarche among school girls in urban West Bengal. *Indian J. Child Health* 11:119-125, 1962.
61. Wilson, D. C., and Sutherland, I. Present age of menarche in Southern England. *J. Obst. & Gynaec. Brit. Emp.* 67:320-322, 1960.
62. Reynolds, E. L., and Wines, J. V. Individual differences in physical changes associated with adolescence in girls. *Am. J. Dis. Child.* 75:329-350, 1948.
63. Nicolson, A. B., and Hanley, C. Indices of physiological maturity: derivation and inter-relationships. *Child Develop.* 24:3-38, 1953.
64. Eveleth, P. B. Eruption of permanent dentition and menarche of American children living in tropics. *Human Biol.* 38:60-70, 1966.
65. Boas, F. Studies in growth. *Human Biol.* 4:307-350, 1932.
66. Grant, J., Wilson, D. C., and Sutherland, I. Blood groups and age of menarche. *Brit. M. J.* 2:140, 1956.
67. Land, G. M. Van't., and Haas, J. H. Menarche-leeftijd in Nederland. *Nederl. tijdschr. v. geneesk.* 101:1425-1431, 1957.
68. Zukowski, W., Kmietowicz-Zukowska, A., and Gruska, S. Age at menarche in Polish girls. *Human Biol.* 36:233, 1964.
69. Tom, F., and Tom, P. Age of menarche in Jamaica. *West Indian M. J.* 15:83-88, 1966.