Sexual maturation in contemporary American girls

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THE AGE AT MENARCHE (first menstruation) provides an excellent indicator of the over-all rate of gonadal maturation for an individual or a population. Numerous studies (cited by Tanner[1] and by Zacharias and Wurtman[2]) give ample evidence that the age at menarche is not fixed but varies from population to population and changes with time. It apparently can be delayed by certain socioeconomic and health influences (e.g., poor nutrition and disease), and accelerated by residence in an urban community and by blindness.[1-4] As Michelson[5] has stated, ". . . the average age at sexual maturity is a statistical concept which has no actual reality and merely serves to express the rate of development of a specific generation in a particular environment."

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Supported by a grant (HD 01582) from the United States Public Health Service.

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***Participation in this project supported by grants from the United States Public Health Service (AM-11709) and the National Aeronautics and Space Administration (NGR-22-009-272).*

Since it cannot be assumed that the chronology of these maturational events will be the same in different populations, or even in the same population at a different time or under different environmental circumstances, it is necessary to study each population separately and to make periodic re-examination of the findings. Furthermore, in order to study the relationship between a particular genetic or environmental factor and sexual development, comparisons should be made between groups who are maturing at approximately the same time and who live under similar conditions.

In the course of comparing the ages at menarche in blind and sighted girls,[3, 4] it became evident to us that satisfactory contemporary data on the natural history of sexual maturation are not numerous. For this reason, we made a study of sexual maturation in the generation of American girls who have attained menarche during the past decade. The study was designed to obtain information on the sequential manifestations of sexual maturation and to examine the effect of genetic constitution, disease states, and various environmental factors on this pattern. We have attempted to derive from this information an empirical formula for predicting the appearance of menarche in a particular girl, in terms of her previous developmental history, her familial tendencies, and her health status.

Subjects and method

The influence of various factors on sexual maturation was studied retrospectively in a population of 6,217 students enrolled in American nursing schools. The girls were all born and reared in the United States; at the time the survey was made (1964 to 1965), they were 17 to 24 years old.

Organization of study. Letters describing our study and its purpose were sent to the directors of 78 accredited schools of nursing throughout the United States; 65 schools (84 per cent) in 35 states agreed to cooperate. Ten thousand and fourteen questionnaires were distributed to the students by the administrative officers of participating schools. Each questionnaire was accompanied by a dated letter explaining the objectives of the study and requesting that the questionnaire be returned within 2 weeks. (This period allowed time for the girls to confirm their recollections by consulting their mothers and sisters.) The questionnaire asked for information concerning: (1) the student's birth date, height, weight, and medical history; (2) the age at which each of the signs of puberty (i.e., breast development, axillary and pubic hair, first menstrual period) appeared; (3) the age at which the menses became regular; (4) the age at which the menses became painful; (5) the present character of the menses; (6) the ages at menarche of the subjects' mothers and sisters. We requested that ages be given as carefully as possible and suggested ways by which the accuracy of recollection could be improved. We also asked that imprecise or uncertain answers be indicated by qualifying phrases such as "about 13" or "almost 14."

Sixty-two per cent (6,217) of the girls who received questionnaires returned them answered. Among these, 4,844 (78 per cent) were judged "normal" on the basis of negative health records. The remaining 1,373 girls (22 per cent) were separated from the total population and grouped into 26 exclusion categories according to diagnosis. Sixteen of these categories contained a sufficient number of subjects to permit separate analysis. (Nine exclusion categories contained fewer than 10 girls, i.e., those with purpura, Stein-Leventhal syndrome, tuberculosis, metabolic deficiency, marked hearing loss, marked reduction in vision, repeated hospitalizations, history of prolonged unconsciousness, or disorders of the central nervous system. Seventy-seven girls who returned questionnaires were older than 24 years; they were also excluded from the study.)

The data on age at menarche were divided into 2 sets with respect to precision: "adjusted" and "unadjusted." In our judgment, imprecise information was given by 32 per cent of the respondents, those who indicated that their answers were only approximate. For this set each menarche age was adjusted by the addition of 6 months, in an effort to distribute the possible error of whole-year reporting. The unadjusted set (obtained from 68 per cent of the respondents) consisted of data from girls who (1) indicated the use of appropriate aids to recollection (e.g., "spring vacation when I was 13" or "at camp, the summer after my twelfth birthday"); (2) gave menarche age in years and months; or (3) provided the exact date on which menarche had occurred. In the "unadjusted" set, for those girls whose menarche age was given to the nearest month (i.e., Groups 2 and 3), it was possible to refine the data further by identifying a subset of the "unadjusted" set, designated "unadjusted and precise."

Table I gives the mean ages at menarche in months for the total and normal populations and for all 3 levels of data refinement. The small difference in mean menarcheal age among these 3 levels (little more than a month) suggests that recollected data are

Table I. Mean age at menarche (all subjects and normal subjects)

Data	Subjects	No. of subjects	Age at menarche (months)	
			Mean	± S.D.
All data (adjusted and unadjusted)	All subjects	6,217	151.7	14.6
	Normal subjects	4,844	151.8	14.1
Unadjusted data	All subjects	4,217	150.4	14.3
	Normal subjects	3,293	150.5	13.9
Unadjusted and precise data	All subjects	2,520	150.3	14.9
	Normal subjects	1,862	150.3	14.4

satisfactory if the samples are large enough and that adjustment by the addition of 6 months did indeed, to a large extent, distribute the error inherent in whole-number reporting.[6]

The subjects were grouped and analyzed by populations as follows: all subjects; all normal subjects; all normal subjects in each school, state, or geographic region;* subjects in each exclusion group which contained 10 or more girls with definite diagnosis; and subjects at 4 different levels of obesity (0 to 10 per cent, 11 to 20 per cent, 21 to 30 per cent, and greater than 30 per cent above normal, as determined by comparison of their heights and weights with tables provided by the Metropolitan Life Insurance Company).

The mean ages (and standard deviation) at menarche, the appearance of axillary hair and pubic hair, the advent of breast budding, the establishment of regular menstruation, and the onset of painful menstruation were calculated for each population. Similar calculations were made for the ages at menarche of the subjects' mothers and sisters.

Correlation coefficients were calculated for the relationship of the subjects' ages at menarche to other events of their sexual development.

Quality of data. In studying the age at menarche, prospective† or status quo‡ studies are, for the most part, regarded as more reliable than retrospective* studies since there are certain defects which may characterize data which have been obtained retrospectively. For instance, there may be inaccuracies in reporting due to memory limitations, to bias associated with nonresponse, or to misreporting, deliberate or unconscious, in order to appear "normal" (although the 2 latter difficulties might be encountered in prospective or status quo studies as well).

In the present study, the first source of inaccuracy was reflected in the marked tendency of the subjects to report the age at menarche in multiples of 6 months. The number of girls who gave their age at menarche in terms of years or half years was 2½ times as high as would be expected, if the month residue was randomly distributed. Even among the girls who actually reported that menarche had occurred on a specific date (or month), there were about twice the expected number at 6 month multiples.

Because of the apparent clustering at half-year intervals, the data were grouped into intervals of 6 months and plotted as a histogram (Fig. 1), together with the normal frequency distribution curve having the same mean and standard deviation. Although the frequency distribution of our sample was fairly symmetric and bell shaped, it was decidedly abnormal, as shown by its excessive peaking around the mean. One possible explanation for this peaking might be that age at menarche is not normally distributed. Another possibility is that

*Because the land mass of the United States encompasses great physical variety the states were grouped into 8 geographic regions, on the basis of location and of socioeconomic similarities (see Table II).

†Studies in which girls who have not yet started to menstruate are questioned at planned intervals over a long period of time concerning the advent of menarche.

‡Studies in which each girl is asked only her age and whether she has already experienced menarche.

*Studies in which girls or women are questioned about their age at menarche after this event has occurred.

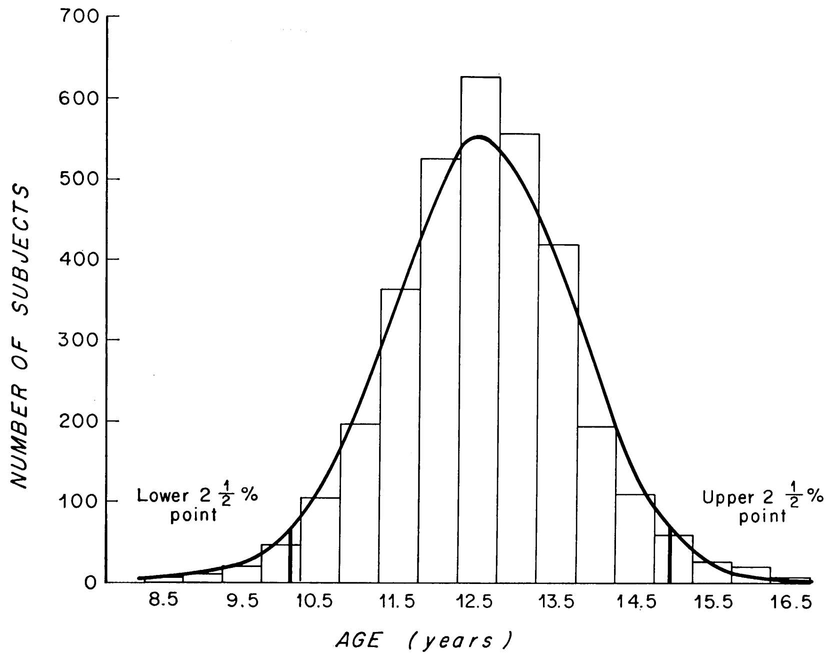

Fig. 1. Histogram of age at menarche for normal subjects.

it is indeed normally distributed, but that the data are biased towards the center. Such bias might enter if, because of faulty memory or reluctance to be classified as "abnormal," some girls who had experienced menarche either before or after the commonly accepted norm of 12 to 13 years had reported their menarche as having occurred during this interval. It has been pointed out that the abnormal peaking was also seen in the subset of girls who reported the exact date or month of their menarche.

Another common source of error in retrospective, as well as prospective and status quo, studies is bias caused by nonresponse. In the present survey, approximately 38 per cent of the girls polled failed to answer the questionnaire. This could have presented a serious problem, since girls who did not answer may have differed in their maturation patterns from the respondents. For example, girls whose maturational history had been in some way unusual might have been reluctant to answer the questionnaire used in this study. (Indeed, this might provide another explanation for the excessive peaking of the age at menarche in the 12 to 13 year interval.)

Fortunately, the significance of nonresponse could be assessed by determining whether the proportion of girls in a given state or region who responded to the questionnaire was related to the proportion of normal girls in the responding group. Fig. 2 represents a scatter plot of the per cent normal and per cent responding in each state. The points appear to be randomly scattered and do not reveal any particular patterns in per cent normal between states which had very low versus very high response rates. Similarly, Fig. 3 shows the mean age at menarche plotted for those states with less than 50 per cent or greater than 75 per cent response. Again, there are no apparent differences. These limited checks suggest that our results were not biased by nonresponse. However, the only certain way of resolving the question of nonresponse bias in our study would be to survey a random sample of the nonrespondents and determine whether their maturational characteristics differed markedly from those of the initial respondents.

Several studies have shown that recollected data on menarcheal age may compare favorably with data collected by the

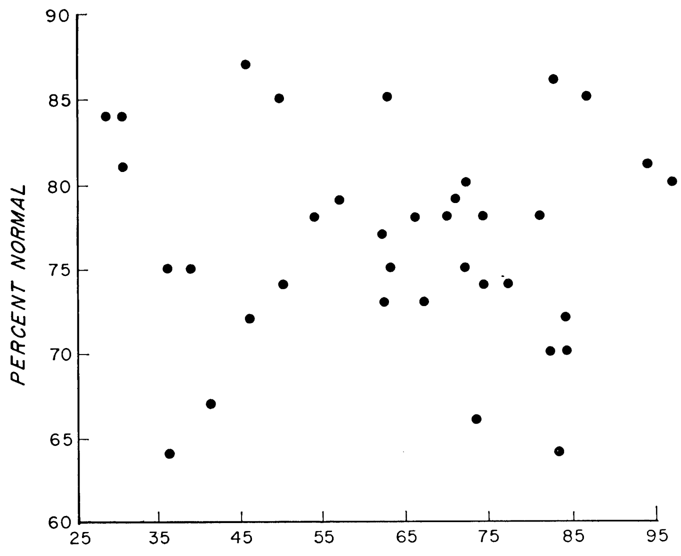

Fig. 2. Scatter plot of the correlation between per cent normal and per cent responding to the questionnaire, in each state.

status quo or even the prospective method. Bojlén and associates[7] found that the mean age at menarche obtained from recollected data agreed with the figure arrived at by the status quo method, if the interval between the event and the time of questioning was not too long. The remembered menarcheal ages were higher and exhibited greater variation the higher the age of the subject at the time of investigation.* Reymert[8] reports good agreement (correlation coefficient 0.77 ± 0.02) between the recalled age at menarche and prospective data on the same girls, obtained 3 years earlier. Livson and McNeill[6] compared the actual ages at menarche, obtained prospectively in 43 girls, with the menarche ages recalled by the same women 2 decades later. They found a 6 month systematic error of underestimation in the recalled data. (It should be noted that we have adopted the convention of adding 6 months to all menarche ages which were reported imprecisely.)

*The adventage of making a retrospective study as soon as possible after the event in question is obvious. However, when the age at menarche of a young group is being investigated, account must be taken of those girls who have not yet reached menarche, since the calculation of the mean age of those girls who have attained menarche would be biased in favor of an earlier menarcheal age in the young group. Since the girls in the present study were 17 to 24 years old, this possibility did not present an appreciable problem.

Results

Recognizing the possible inadequacies of our data, we have attempted to analyze them as if they were unbiased and normally distributed.

Regional patterns in normal girls. Table II shows the mean age (in months) at the advent of various maturational events for girls in each geographic region. The events are arranged in the table in chronologic order, and the regions are ranked in increasing order of age at menarche. It is interesting to note the high degree of consistency in the table, in that the ranking of regions is not very different from one maturational event to another. For example, the East Central region is lowest for all variables, while the Northwest region is highest for 3 of the variables and almost highest for the remaining 3. An analysis of variance was performed for each of the 6 variables to determine whether the differences between regions were statistically significant. The results indicated highly significant differences (0.005 significance level) in age at menarche between regions. That is, the probability that sampling fluctuations alone could have produced differences in age at menarche as large as those observed between the regions is less than 0.5 per cent. None of the other variables, however, appeared to indicate significant regional differences.

Table II also reveals much larger variations in age at onset of regular and painful menstruation than in any of the other events studied, as indicated by the standard deviations computed for each of these events. This is consistent with the widespread clinical impression that the age at which menstruation becomes regular is more variable

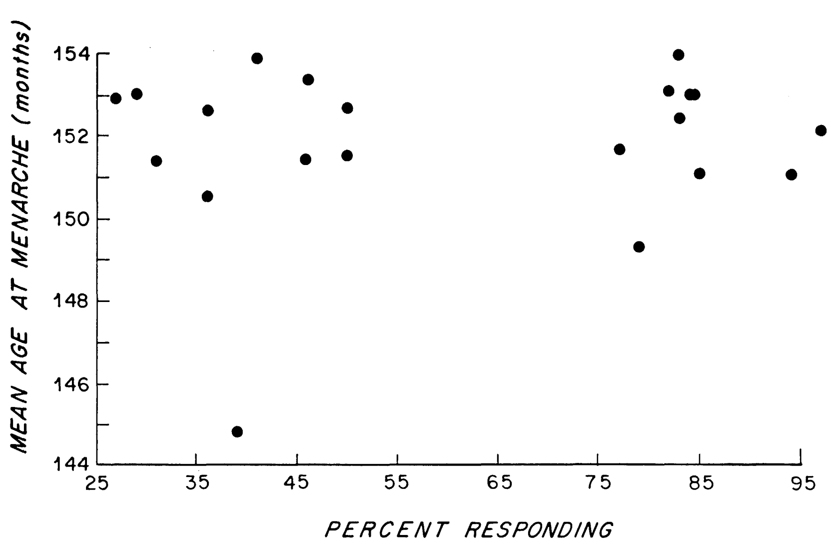

Fig. 3. Scatter plot of the correlation between the mean age at menarche and the per cent responding, for states with less than 50 per cent or more than 75 per cent response.

Table II. Mean age (months) at advent of various maturational phenomena in normal subjects

*Geographical regions**	*No.†*	*Pubic hair*	*Breast budding*	*Axillary hair*	*Menarche*	*Regular menses*	*Painful menses*
East Cent.	239	141.0	141.7	143.5	149.1	161.1	170.7
Mid. Atl.	1,265	141.4	142.2	144.1	151.0	164.7	173.1
New Eng.	644	142.1	143.1	145.6	151.5	164.2	175.6
North Cent.	438	142.4	143.6	145.2	152.1	165.3	176.0
Southeast	579	143.4	143.4	144.7	152.3	166.3	176.3
Southwest	449	142.3	143.1	145.6	152.5	165.5	180.0
Midcent.	672	143.7	143.4	145.5	152.9	166.5	175.7
Northwest	558	143.9	143.7	145.4	153.0	165.6	177.5
Total normal		142.5	143.0	144.9	151.8	165.2	175.4
Standard deviation		13.9	14.5	15.1	14.1	24.2	29.8
Standard error		0.21	0.21	0.23	0.20	0.39	0.65
Sample size	4,844	4,390	4,683	4,395	4,844	3,830	2,072

*Geographical regions: East Central—Illinois, Kentucky, Ohio, West Virginia; Middle Atlantic—District of Columbia, Maryland, New Jersey, New York, Pennsylvania; New England—Connecticut, Massachusetts, New Hampshire, Rhode Island, Vermont; North Central—Michigan, Minnesota, Wisconsin; Southeast—Alabama, Florida, Louisiana, Mississippi, Tennessee, Virginia; Southwest—Arizona, Southern California, Oklahoma, Texas, Utah; Midcentral—Iowa, Kansas, Missouri, North Dakota; Northwest—Northern California, Montana, Oregon, Washington.

†No. = number of subjects.

than the age at menarche. Fig. 4 shows the mean age at each maturational event for normal girls.

Table III compares the mean age at menarche of the subjects and that of their mothers and sisters, by region. It is readily apparent that the mean age at menarche among the mothers was about 4.5 months greater than that of the girls themselves. The difference is highly significant, as indicated by the standard errors of estimate, and is evident in every region. This finding supports the hypothesis that the onset of menarche is occurring earlier in the present than in the preceding generation. The age at menarche for sisters did not differ significantly from that of the subjects.

Analysis of exclusion categories. Table IV lists the 18 exclusion groups containing 10 or more girls, ranked in order of mean age at menarche. Interest centers on the question of identifying those groups which differ from the normal group with regard to age at menarche. The correct identification of such groups is difficult, and the techniques employed must be chosen with care.

If it is assumed that each of the 26 groups represents a sample from the normal population (i.e., that the age at menarche in the exclusion groups is the same as in the nor-

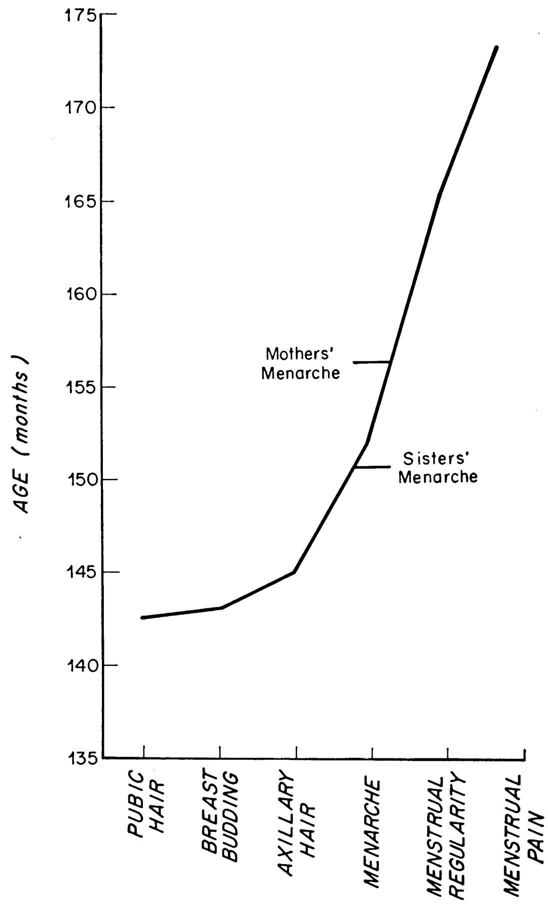

Fig. 4. Mean age at advent of various maturational events in normal subjects.

Table III. Mean age at menarche (months) of normal subjects and their sisters and mothers

Geographical regions	No. of subjects	Mean age at menarche in months: Subject	Sister	Mother
East Cent.	239	149.1	148.7	153.4
Mid. Atl.	1,265	151.0	150.2	155.4
New Eng.	644	151.5	149.4	156.1
North Cent.	438	152.1	150.7	157.5
Southeast	579	152.3	150.6	155.1
Southwest	499	152.5	152.5	158.1
Midcent.	672	152.9	151.5	157.6
Northwest	558	153.0	150.2	155.6
Mean		151.8	150.5	156.1
Standard deviation		14.1	13.5	18.7
Standard error		0.20	0.27	0.31
Sample size		4,844	2,432	3,712

Table IV. Mean age at menarche (months) among subjects excluded for health reasons

Exclusion	*Mean* $(\bar{X}_i)$ *(mo.)*	*Standard deviation* (S_i) *(mo.)*	*Sample size* (n_i)	*Normal deviate* $z_i = \sqrt{n_i}\,(\bar{X}_i - 150.5)/13.9$	*95% joint confidence interval (mo.)*
Obesity	147.0	15.3	463	−5.42	145.0 – 149.0
Anemia	149.2	14.5	24	−0.46	140.4 – 158.0
Thyroid disorder	149.4	15.8	227	−1.19	146.5 – 152.3
Cardiac disorder	149.6	13.5	13	−0.23	138.0 – 161.2
Chronic illness	149.6	13.7	25	−0.32	141.0 – 158.2
Psychiatric disorder	151.4	21.4	11	0.22	138.4 – 164.4
Rheumatic fever	151.7	13.4	58	0.66	146.0 – 157.4
Epilepsy	152.7	14.8	19	0.69	142.8 – 162.6
Over age (birth date before 1940)	153.1	14.1	77	1.64	148.2 – 158.0
Diabetes	153.5	17.0	11	0.72	140.5 – 166.5
Developmental anomaly	153.8	14.8	37	1.45	146.7 – 160.9
Thyroid medication for menstrual irregularity	154.5	15.6	38	1.78	147.5 – 161.5
Serious illness	155.7	17.2	24	1.83	146.9 – 164.5
Endocrine disorder	157.1	24.4	19	2.07	147.2 – 167.0
Urogenital disorder	159.8	23.8	13	2.42	148.2 – 161.4
Migraine	161.3	8.1	13	2.80	149.7 – 172.9
Paralytic polio	161.8	13.7	12	2.82	149.8 – 173.8
Normal (unadjusted data)	150.5	13.9	3,293	0.0	

mal group), then sampling fluctuations alone would be expected to produce large observed differences from the normal group in a few of the exclusion groups. Therefore, it is not appropriate to compare each of the exclusion groups with the normal group by means of ordinary t tests, since we would normally expect to find one or 2 large t values in a population divided at random into 26 groups, even if there were no real differences among these groups. Such a procedure would probably lead to the assertion that several of the groups differ significantly from the normal group, when in fact some of these differences might be the result of sampling errors. Although this procedure would probably identify true differences, it would do so at the expense of incorrectly ascribing statistical significance to groups which did not really differ from the normal group.

At the other extreme, one may follow a procedure which would declare as significant only those groups which differ by very large amounts from the normal group, at the expense of failing to identify other intermediate groups which differ significantly. We have, in our analysis, employed both types of procedures; those groups which are declared to be significantly different from the normal group by the second procedure may be regarded as differing with a high degree of confidence. The additional groups which might appear to be significant by the first procedure may be regarded as possible subjects for further investigation.

Procedure 1. Since the normal sample contains more than 3,000 observations, we may, without substantial loss of statistical accuracy, regard it as a population with known mean of 150.5 and standard deviation of 13.9. Column 4 of Table IV shows the normal deviates z_i corresponding to observed differences between the means of each of the exclusion groups and the normal group. Exclusion groups corresponding to normal deviates which are larger than 2 in magnitude might, with the use of Procedure 1, be deemed statistically significant at the 5 per cent level of significance. These groups are obesity, endocrine disorder, urogenital disorder, migraine, and paralytic polio.

It should be noted that the above tests do not correspond to a 5 per cent significance level for all exclusion groups but rather for each one separately. That is, we cannot say with 95 per cent confidence that all 5 groups differ significantly from the normal group. To make the latter statement it would be necessary to employ a multiple comparison test (Procedure 2). Such a test is very conservative in that it identifies only extremely large differences, especially when there are a large number of groups under consideration.

Procedure 2. The appropriate test in this case is the one given by Dunnet[9] for comparing several treatments against a control. It provides a method for making confidence statements about the true values of the differences between each of a set of means and the mean of a control group. In this procedure, the probability that all such confidence statements are simultaneously correct is equal to a specified value, p.

Although Dunnet's tables do not cover the sample sizes of our study, we can approximate the correct probability levels adequately by assuming the normal (or control) group to have a known mean and standard deviation equal to those observed in the sample. Since there are more than 3,000 observations in this group, the correlation between any 2 t statistics will be very close to zero, and we can approximate Dunnet's procedure by assuming statistical independence among the various z_i given in Table IV. If we wish to make 95 per cent confidence statements about the observed differences between the normal group and each of the 26 exclusion groups, we must find a probability p such that $p^{26} = 0.95$. This value of p (0.998) may then be applied to each of the observed differences separately. The normal deviate corresponding to a 2-sided confidence interval at level 0.998 is found (in any table of the normal distribution) to be $z = 3.09$. To apply this test, we compare each of the observed deviates z_i with 3.09 and declare as significant those which are as large or larger in magnitude than this value. Only the obesity group, with a z value of –5.42, is clearly significant according to this test (Table IV). Indeed, the obesity group would stand out as significant at a level much less than 0.001. If, however, we were to operate at the 90 per cent confidence level instead of the 95 per cent level, the critical value for testing would be reduced from 3.1 to 2.8, so that the paralytic polio and migraine groups would also be judged significantly different from the normal group.

Another interpretation of Table IV is obtained from the confidence intervals in Column 5. We may stipulate with 95 per cent confidence that the true means of the 26 exclusion groups all lie within the indicated intervals. The interval for the obesity group, 145 to 149, is the one which does not include the normal group mean of 150.5.

A final point worth noting with respect to Procedures 1 and 2 is that both are based on the assumption of equal variances among groups. A procedure for testing equality of the variances, similar to Procedure 2 for testing equality of means, shows that the variances for obesity, thyroid disorder, endocrine disorder, and urogenital disorder all appear significantly higher (at the 0.05 level of significance) that those for the normal group. These indications of large variances may be indicative of basic differences in these groups with regard to the physiology of menarche.

Since the obesity group stands out statistically as being significantly different from the normal group, its patterns were analyzed in greater detail by subdividing it into 4 levels of obesity. A pattern is seen in the first 3 obesity levels, the mean age at each maturational event decreases with increasing obesity. However, this pattern is reversed in the most obese group (Table V and Fig. 5). Fig. 6 suggests that menarche also occurs earlier in the mothers and sisters of obese girls.

A predictive model for menarche. Using data from the group of normal girls, we performed a linear regression analysis to determine whether knowledge of the age at onset of breast budding, pubic hair, and

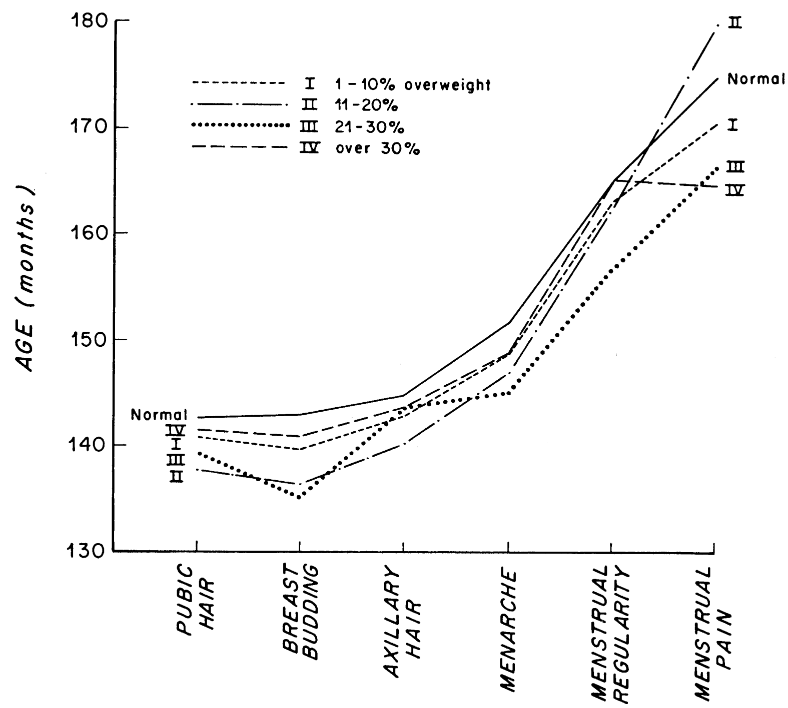

Fig. 5. Obesity and sexual maturation. Mean age at advent of various maturational events in girls at 4 levels of obesity.

Table V. Relation of obesity to sexual development. Mean age (months) at advent of various aspects of sexual maturation in 731 obese girls

*Obesity groups**	*Pubic hair*		*Breast budding*		*Axillary hair*		*Menarche*	
	Mean	*S.E.*	*Mean*	*S.E.*	*Mean*	*S.E.*	*Mean*	*S.E.*
1	140.9	0.65	139.8	0.64	142.9	0.70	149.1	0.68
2	137.9	1.37	136.3	1.22	140.2	1.45	146.8	1.39
3	139.3	2.40	135.2	2.24	143.1	3.57	145.2	2.43
4	141.6	3.15	140.8	2.83	143.2	3.02	148.9	3.49
Total normal girls	142.5	0.21	143.0	0.21	144.9	0.23	151.8	0.20

*On the basis of normal weight-for-height tables established by the Metropolitan Life Insurance Company, obesity groups were defined as follows: Group 1 = < 11 per cent in excess of limit of normal, 524 girls; Group 2 = 11 to 20 per cent in excess of limit of normal, 137 girls; Group 3 = 21 to 30 per cent in excess of limit of normal, 35 girls; Group 4 = > 30 per cent in excess of limit of normal, 135 girls.

axillary hair could be used to predict the age at menarche. Data concerning age at breast budding and age at appearance of pubic hair were found to be useful for this purpose as summarized by the regression equation:

$$Y = 57.8 + 0.373X_1 + 0.286X_2 \pm 2S$$

where Y = age at menarche in months; X_1 = age at breast budding in months; X_2 = age at appearance of pubic hair in months; S = standard error of estimate = 11.1.

Thus, if age at breast budding was noted in a particular girl at 145 months and pubic hair at 140 months, a 95 per cent prediction interval for her age at menarche might be computed as follows:

$$\begin{aligned} Y &= 57.8 + 0.373\ (145) + 0.286\ (140) \pm 22.2 \\ &= 151.9 \pm 22.2 \\ &= 129.7 - 174.1 \end{aligned}$$

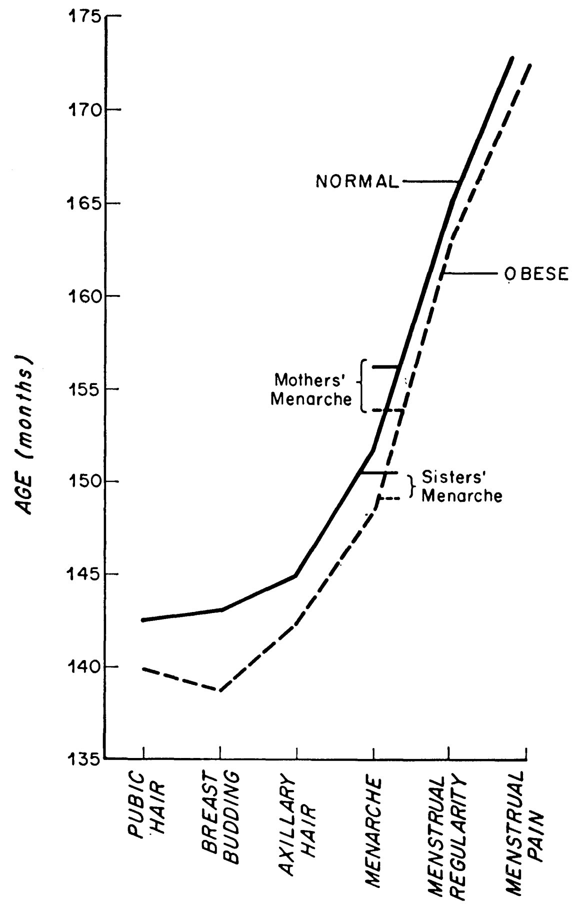

Fig. 6. Patterns of sexual maturation in normal and obese girls. Comparison of mean age at advent of various maturational events in normal girls and their mothers and sisters, and obese girls and their mothers and sisters.

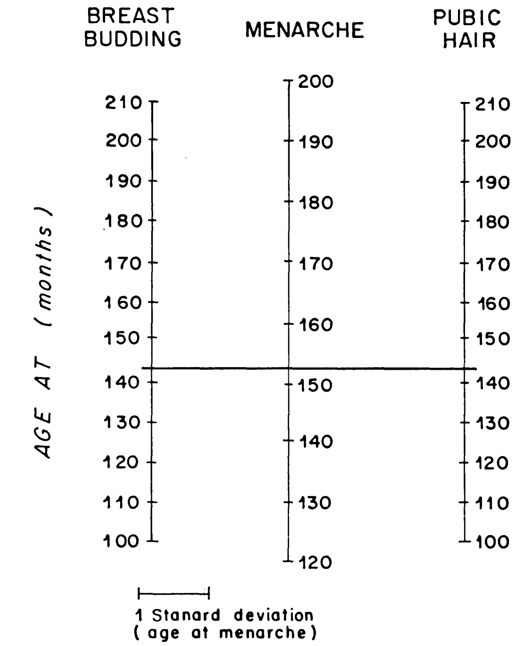

Fig. 7. Nomograph for the prediction of age at menarche from ages at breast budding and appearance of pubic hair.

Table VI. Correlation coefficients among various maturational events

Event	*Menarche*	*Breast budding*	*Pubic hair*	*Axillary hair*
Menarche	1.0	0.6	0.6	0.5
Breast budding	0.6	1.0	0.7	0.7
Pubic hair	0.6	0.7	1.0	0.8
Axillary hair	0.5	0.7	0.8	1.0

It should be noted that this 95 per cent prediction interval spans only 44 months, as compared to the 56 to 60 month span obtained by analysis of menarche data alone (Table I). This computation may be facilitated by use of the nomograph given in Fig. 7. By connecting the figures for the ages at breast budding and appearance of pubic hair on the first and third lines with a straight edge, the answer may be read on the middle scale. The relations between menarche and each of the potential predictor variables may be summarized by their correlation coefficients as shown in Table VI.

Discussion

Our data indicate that the mean age at menarche for 4,844 contemporary normal girls in the United States is 151.8 ± 14.1 months. The sequence of overt maturational events which precedes menarche starts with the appearance of pubic hair at 142.5 ± 13.9 months and proceeds to breast budding at 143.0 ± 14.5 months and then to the appearance of axillary hair at 144.9 ± 15.1 months. Following menarche, regular menstruation is established by 165.2 ± 24.2 months and regular painful menses begin at 175.4 ± 29.8 months (Table II and Fig. 4).

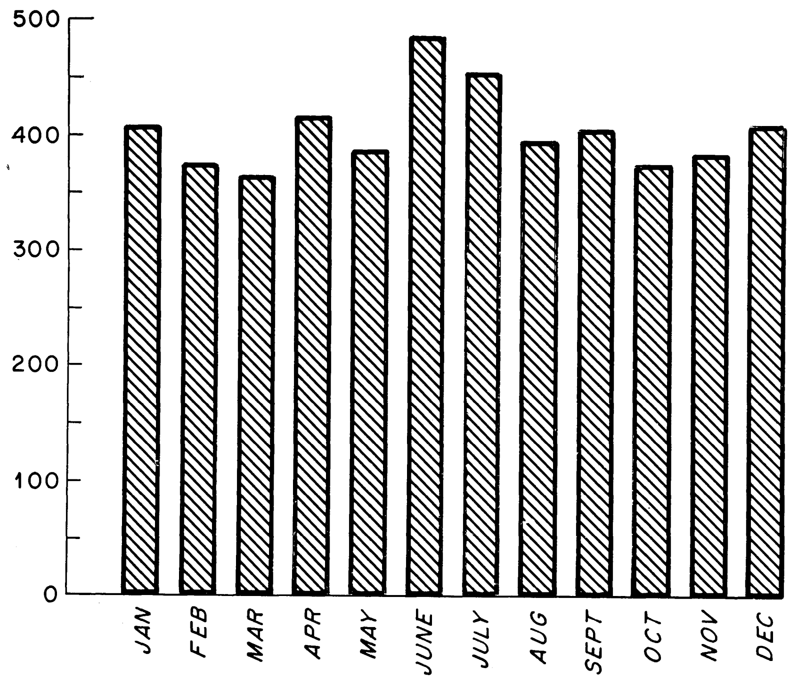

Fig. 8. Season and menarche. Incidence of menarche by month, in normal girls.

The differences in mean age at menarche between various geographic regions of the United States, although statistically significant, are small (Table II). For this reason, the mean age at menarche for the total normal group (151.8 ± 14.1 months) may be regarded as representative of the entire United States at the present time. This suggests that such climatologic factors as mean daily temperature and magnitude of seasonal shifts in day length exert little influence on sexual maturation. None of the other maturational events showed significant regional differences.

The existing literature[1, 2] dealing with factors which modify age at menarche indicates that the most important influences are related to socioeconomic conditions, heredity, and health. The data offered in this report concern several of these factors.

In general, menarche was earliest in the Eastern United States and latest in the Central and Western regions. Differences between the regions were small, and it is difficult to attribute them to a single factor. The tendency for girls in the Northeast to mature more rapidly could perhaps be related to the relatively greater urbanization of this area[10-12] or to the presence in its population of a greater proportion of one or more ethnic groups which tend to exhibit early menarche.

A graph of our data concerning the relationship between season and menarche shows a peak incidence in June and July (Fig. 8). These results are to some extent in agreement with the findings of Bolk,[13] Reymert and Jost,[14] and Richter,[15] but not with those of Engle and Shelesnyak,[16] who reported a constant incidence of menarche during fall, winter, and spring, but a sharp drop in summer. The data of all these studies are consistent with the hypothesis that seasonal changes in day length might modify menarche.

Obesity was associated with premature menarche in our subjects. This effect was proportional to the degree of obesity, in the range of 10 to 30 per cent above standard. The delayed menarche seen in girls who were more than 30 per cent heavier than their allowable maximum suggests that the obesity in these girls resulted from a different primary pathophysiologic disorder than that present in the less obese subjects.

Paralytic poliomyelitis and migraine were found to be associated with delayed menarche. In contrast to previous reports,[17-19] our data failed to demonstrate earlier sexual maturation in diabetic girls. (We were not able to group our diabetic population according to whether the disease had appeared before or after menarche.)

The existence of a secular trend (the lowering of menarcheal age with time) is widely accepted, although in some instances the observations presented in support of this concept are inadequate. The data of the present report offer some confirmation that the secular trend is a real phenomenon; the age at menarche in our subjects was lower by 4.5 months than that of their mothers and also lower than that reported in most previous studies of American girls made during the first half of this century.[2] On the other hand, our data provide no information concerning the cause of this trend, and it is not possible to conclude that it has been the result of improved nutrition, health, or any other factor.

Since menarche often follows breast budding and the appearance of pubic hair by a characteristic number of months, it is possible to utilize the age at which these physical changes are noted to estimate the age at which the first menstrual period will occur. Moreover, it is possible to define an interval during which 95 per cent of normal girls whose breasts and pubes show pubertal changes at given ages can be expected to experience menarche. An empiric formula for calculating this interval is described above (Fig. 7). The determination of these "normal limits" might be of some value in helping the clinician to decide whether menarche in a particular girl is abnormally early or late.

Summary

The mean age at menarche among 6,217 healthy American student nurses was 151.8 months. This age is lower than that reported in most previous studies and is 4.5 months lower than that of the mothers of these subjects. These data are consistent with the hypothesis that menarche is taking place earlier than it formerly took place.

The sequence of overt maturational events which preceded menarche started with the appearance of pubic hair at 142.5 months and breast budding at 143.0 months, followed by the appearance of axillary hair at 144.9 months. Menarche occurred significantly earlier in the Northeastern region of the United States than elsewhere in the country.

Menarche tended to occur prematurely in obese girls, except those weighing more than 30 per cent above normal. Paralytic poliomyelitis and migraine were associated with delayed menarche.

A formula and nomograph are provided to estimate the 95 per cent confidence limits for the appearance of menarche in individual girls for whom the ages at breast budding and the appearance of pubic hair are known.

We acknowledge with gratitude the generous assistance provided by the IBM Cambridge Scientific Center in the processing and analysis of the data presented in this report. In particular, we wish to thank Mr. Patrick E. O'Neil and Mr. John B. Harmon for their contributions in programming and processing the data. We also wish to express appreciation to Dr. Howard Ulfelder for his advice and encouragement, and to Miss Scobie Evans and Miss Elizabeth Grubb for their secretarial and research assistance.

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