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Weight and age at menarche

O STARK,* C S PECKHAM,* AND C MOYNIHAN†

**Institute of Child Health, University of London, and †Academic Department of Radiotherapy, Royal Marsden Hospital, London*

SUMMARY In the National Child Development Study (1958 cohort) information on their age at menarche and their weights and heights measured at 7, 11, and 16 years was available for 4427 girls. The distribution of age at menarche was not influenced by social class. Weight adjusted for height did not play an important part in the timing of sexual maturation of the girls in the study. Relative weight (weight expressed as a percentage of standard weight) at the ages of 7 and 11 years explained only 3·2%, and 4·9%, respectively of the variation in age at menarche, and changes in relative weight between these two ages accounted for 2%. Girls with early menarche were more likely to be overweight at ages 7, 11, and 16 years than those with late menarche, although early menarche was also reported by girls who were underweight or of average weight. These findings support the hypothesis that in well nourished populations the relation between menarche and body size is largely regulated by genetic factors and that nutrition is less important.

Studies in experimental animals have suggested that nutrition has an important effect on sexual development.[1 2] In humans, however, such evidence is mainly circumstantial. Epidemiological and clinical studies show that pubertal development is delayed in undernourished populations[3] and in malnourished children,[4 5] and that early puberty is associated with overweight.[6]

In girls, menarche is an indicator of pubertal timing but the mechanism that controls the onset of puberty and triggers menarche is not known. It has been suggested that early menarche in obese girls may be due to overweight resulting from overeating.[6 7] Some studies do not support this hypothesis, however, and the association between overweight and menarche remains unclear.[8]

Using data derived from the National Child Development Study,[9] we describe the association between age at menarche and relative weight (weight adjusted for height) and estimate the incidence of early menarche in girls who were overweight and underweight at 7 and 11 years of age. As the data are longitudinal it was also possible to relate age at menarche to birth weight and to changes in relative weight between the ages of 7 and 11 years. The hypothesis[10] that nutrition plays a leading role in the timing of the menarche is discussed in the light of the findings of the study.

Method

The National Child Development Study (NCDS) is a longitudinal follow up study of all children in England, Scotland, and Wales who were born in one week in March 1958. The original cohort of nearly 17 000 was studied at birth and again at the ages of 7, 11, and 16 years. Information on health, education, family, and socioeconomic class was collected at each follow up visit.

At the medical examination when they were 16 years old, girls were asked at what age they had first menstruated. Of those who responded, 4427 had had their weight and height measured when they were 16, 3653 when they were 7, and 3675 when they were 11 years old. Complete information on age at menarche and weight and height at 7, 11, and 16 years of age was available for 3018 girls. The analysis of response rates and the assessment of expected weight for height have been previously described.[11] Relative weight, which is observed weight expressed as a percentage of the weight expected from a regression of log weight on log height, was calculated for each girl at each age. This assumes that expected weight=$c(\text{height})^p$, where c and p are constants. Overweight was defined as weight that exceeded the expected weight by 20% (relative weight more than 120). In the previous study of prevalence of overweight[11] children from

multiple births, illegitimate births, and immigrants were excluded, but in the current analysis the whole cohort was included.

The validity of recalled data about age at menarche was assessed by comparison with data from a study of growth in girls born in 1962 in Newcastle upon Tyne who were examined at half yearly intervals between the ages of 9 and 17 years.[12] These girls recorded the date of their first menstruation on a calendar. The cumulative frequency of age at menarche in both cohorts was compared up to the age of 16 years. Slightly more girls had earlier menarche in the NCDS than in the Newcastle study but the difference was not significant (Kolgorov-Smirnov two tailed test $p>0{\cdot}1$) (table 1). Comparison after this age was not possible because 94 girls in the NCDS had not yet menstruated at the time of the interview, which took place shortly after their 16th birthday. The Newcastle upon Tyne survey continued up to the age of 17 years and the age at menarche was known for all the girls.

Table 1 *Age at menarche in the National Child Development Study (n=4427) and the Newcastle upon Tyne study (n=699)*

Age at menarch (years)	*National Child Development Study (cumulative %)*	*Newcastle upon Tyne study (cumulative %)*
−11	2·2	1·7
−12	15·4	11·2
−13	39·4	38·8
−14	73·1	71·1
−15	92·7	92·4
−16	97·7	98·9

Results

AGE AT MENARCHE AND SOCIAL CLASS

Social class had no significant effect on the distribution of age at menarche among the girls in the NCDS.

AGE AT MENARCHE AND RELATIVE WEIGHT

The relative weight distribution at 7, 11, and 16 years of age for each age at menarche is shown in table 2. To preserve the largest possible numbers in the marginal groups the data presented are cross-sectional and numbers vary among age groups. The numbers included at the age of 16 were larger than at younger ages because information on both age at menarche, and height and weight, were obtained at this examination. A larger proportion of girls with early menarche were heavier for their height at all ages than those with late menarche. The distribution of relative weight for each age at menarche followed a similar pattern at the ages of 7, 11, and 16 years.

Table 2 *Menarche and relative weight distribution at ages 7, 11, and 16 years*

Age at menarche (years)	*Age at measurement (years)*	*No of girls*	*Relative weight (%)*		
			<100%	*101–120*	*>120*
<11:	7	79	29	53	18
	11	76	31	49	20
	16	97	30	52	18
11:	7	478	46	44	10
	11	478	40	45	15
	16	585	36	49	16
12:	7	903	51	43	6
	11	898	54	34	12
	16	1066	46	44	11
13:	7	1244	58	38	5
	11	1245	60	33	8
	16	1494	56	38	7
14:	7	695	64	33	3
	11	722	68	24	6
	16	864	66	30	5
>14:	7	180	71	26	3
	11	181	73	24	3
	16	277	78	20	2
Not yet reached menarche:	7	74	72	27	1
	11	75	76	21	3
	16	94	93	7	0

BIRTH WEIGHT, RELATIVE WEIGHT AT 7 YEARS, AND AGE AT MENARCHE

Birth weight and menarche were not related. The relation between birth weight, relative weight at the age of 7, and age at menarche was complex (table 3). Relative weight above average (over 100) was found in a greater proportion of girls with birth weight above the 90th centile (58%) than below the 10th centile (33%). Within each birth weight group relative weight over 100 was more common among girls with early menarche than those with late menarche.

CHANGES IN RELATIVE WEIGHT BETWEEN THE AGES OF 7 AND 11 YEARS, AND THE AGE AT MENARCHE

The association between the age at menarche and changes in relative weight during the period preceding the onset of menstruation (7–11 years) was weak. In 106 girls whose relative weight remained above 120, 36 (34%) reported menarche before the age of 12 and similar early menarche was also reported by 13 (22%) of 60 girls whose relative weight was reduced from above 120 to below 120; this difference was not significant ($p<0{\cdot}1>0{\cdot}05$). Likewise the difference in the proportion of girls with early menarche (17 of 267, 6%) who remained underweight (relative weight less than 90) and those whose relative weight increased from below 90 to above 90 (18 of 170, 11%) was not significant ($p>0{\cdot}1$). For the whole NCDS population the proportion of variance explained by changes in relative weight between 7–11 years was 2% and was significant ($p<0{\cdot}0005$).

VARIATION IN AGE AT MENARCHE EXPLAINED BY WEIGHT, HEIGHT, AND RELATIVE WEIGHT

Weight (not corrected for height) at the ages of 7 and 11 years explained 6·5% and 18%, respectively, of the total variance in the age of menarche, whereas weight changes between the ages of 7 and 11 years explained 13%. The proportion of variance explained by relative weight, however, was smaller than that explained by weight or height independently (table 4). This difference can also be illustrated by correlation coefficients between age at menarche and weight, height and relative weight, which were −0·25, −0·19, and −0·18 at the ages of 7 years, and −0·43, −0·39, and −0·22 at the age of 11 years. These findings reflect the fact that—during growth—height and weight continue to increase, but relative weight may increase, decrease, or remain the same.

Table 3 *Association between relative weight at age 7, birth weight, and age at menarche*

Total No of subjects	*Birth weight centiles*	*% With relative weight above average at 7 years old by age at menarche (years)*				
		Total %	*<12*	*12*	*13*	*≥14*
267	<10	33	52	28	31	34
432	10–24	43	57	47	40	34
835	25–49	42	49	48	38	33
753	50–74	44	64	49	42	31
481	75–89	46	64	51	42	39
313	>90	58	64	63	57	46

Thirty one girls with gestational ages below 30 and above 44 weeks have been excluded.

Table 4 *Percentage variation in age of menarche explained by relative weight, weight, and height*

Age (years)	*Relative weight*	*Weight*	*Height*
7	3·2	6·5	3·5
11	4·9	18·0	15·1
Change between the ages of 7 and 11	2·0	13·1	

All differences are significant ($p<0{\cdot}0005$).

Discussion

In our study the association of early menarche and increased weight for height begins well before the onset of puberty, and persists into late adolescence. This is consistent with recently published results from a longitudinal study of 78 boys,[13] which showed that those who matured early were already heavier at 6 months of age. Studies reviewed by Tanner[14] also suggested that early puberty was associated with increased body size throughout childhood.

We have found that 18% of girls with menarche before the age of 11 years were overweight at the age of 7, but only 3% of those with menarche after the age of 14. Wolff attributed advanced sexual maturation in overweight girls to the influence of excessive energy intake on growth.[6] Frisch proposed that the onset of menstruation was dependent on attainment of a critical body weight for height that represents a critical composition of relative fatness, and that menarche occurs early in obese girls because they achieve this critical relative weight at an earlier age.[7] Her hypothesis (although widely publicised) has not been supported by the results of other studies.[8 15–17] Garn and Bailey analysed data from 550 mother/daughter pairs and showed that the correlation coefficient between the mothers' fatness and menarche was −0·11 and the daughters' fatness

and menarche was −0·14; the correlation between mothers' and daughters' menarche was 0·25, and after correction for fatness was 0·23.[18] They concluded that the degree of fatness in girls had little effect on the association between the mothers' and daughters' ages of menarche.

Although early menarche was more common in overweight girls in this study, it also occurred in those who were underweight or whose relative weight declined between 7 and 11 years of age. Relative weight at the ages of 7 and 11 years explained only 3·2 and 4·9% of the variation in age at menarche, and changes in relative weight between these two ages accounted for 2%. These findings indicate that weight for height did not play an important part in the timing of sexual maturation. The weak association between relative weight and age at menarche makes it unlikely that nutrition had a decisive influence on the timing of menarche. If nutritional factors do have any effect on the timing of puberty they seem more likely to be important before the age of 7 when the association between relative weight and menarche is established. Liestol, who studied secular changes in the age at menarche, also considered that the influence of environment in the first years of life was the most important.[19]

Information on diet was not collected in our study but Mills *et al* in the United States found no correlation between pubertal status in 14 year old boys and their intake of calories, protein, and other nutrients, and diet recorded every three years from birth failed to explain increased weight in those who matured early.[13] He suggested that there may be a factor present in early life that mediates growth and the onset of puberty, and that the association between the timing of puberty and body size may be controlled by genetic influence. The influence of heredity on the early origin of obesity in girls with early menarche needs to be assessed in a more detailed study. Our finding that relative weight at the age of 7 years was associated with birth weight and age at menarche, and that birth weight and menarche were not, needs further clarification.

The relative importance of environmental and genetic factors varies among populations. The delaying effect of malnutrition and poverty on sexual maturation has been observed in many developing countries.[3] In industrialised societies the age at menarche has decreased over the past 100 years and this trend has been attributed mainly to improvements in health and nutrition.[20] There is evidence that this trend is not continuing in some European countries, including Great Britain.[3] The children in our study were born in 1958 and grew up during a time of economic prosperity when there was an adequate national food supply. This may explain why the distribution of age at menarche was not influenced by social class and that nutritional factors were not decisive for the timing of menarche. Marshall proposed that if 'environment provides requirements for good nutrition and health the variability of the menarcheal age within the population may be mainly due to genetic factors.'[21] The findings from NCDS are consistent with this hypothesis.

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Correspondence to Dr O Stark, Institute of Child Health, 30 Guilford Street, London WC1N 1EH.

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