A MIXED-LONGITUDINAL STUDY ON THE PATTERN OF PUBERTAL GROWTH: RELATIONSHIP TO SOCIO-ECONOMIC STATUS AND CALORIC-INTAKE—IV

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ABSTRACT

The pubertal growth pattern was observed on 791 girls belonging to upper and low SES. These girls ranged between 7-16 years. The effect of calorie intake on the pubertal growth was also ascertained.

The development of breast was first to appear at the age of 8.25 years. It was followed by pubic and axillary hair development. The mean age of menarche was 12 years and 12.8 years for USES and LSES, respectively. The onset of menarche, breast and pubic hair was significantly delayed in LSES girls by 0.8 years. Menarche was found to correlate better with breast development than pubic or axillary hair.

The girls on adequate calories showed early onset of breast, pubic hair and axillary hair development and of menarche. Similarly, these girls attained mature stage (adult) of these variables earlier compared to those who were on inadequate calories. However, intermittent developmental stages of pubic hair and axillary hair showed no consistency with intake of calories. The girls on inadequate calories showed approximately one year late onset of breast and pubic hair development.

The present observations suggest that the onset of puberty is strongly influenced by environment but its attainment is under the genetical control.

Key words: *Growth, Pubertal, Socio-economic status, Calories.*

The adolescent growth and development represents the important linkage between childhood and fully mature adulthood. It is that important phase of life when the sex functions mature and prepare for procreation apart from other physical and psychological changes occur resulting in emergence of fully functional adult.

Although there is a set of natural sequence in the sexual development yet wide variations occur due to different socio-economic status, food habits and other factors in different populations(1-8).

In our country, there is a great lacuna of such information. Further, the data pertaining to rate at which girls progress through the stages of puberty and about the relation of one event to another is almost lacking. The information is greatly needed.

This paper thus describes:

(*a*) The pattern of development of external secondary sex characteristics in upper and lower socio-economic status;

(*b*) Differences in sexual growth pattern between two SES;

(*c*) Relationship among various sex characteristics;

(*d*) Variation in the time taken to pass through the various developmental stages; and

(*e*) Effect of caloric-intake on the pubertal growth.

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Material and Methods

The girls between 7-16 years of age for this study were the same as for the study of physical growth II.

The development stages of breast, pubic hair and axillary hair were assessed and recorded using the rating system described by Weiner and Lourie(9). Each girl was examined 5 times at 6 monthly intervals using mixed longitudinal design. Age at onset of menarche was recorded by interviewing each girl repeatedly and verified at each point of observation.

Probit analysis(10) was used to calculate the means for the age of onset of various developmental stages of breast, pubic hair and axillary hair and of menarche. Percentiles of these were calculated and illustrated graphically(11). Differences between two SES girls were also ascertained by Chi-square test. Contingency co-efficient method was employed to observe the extent of relation in various secondary sex characteristics. Mean time taken by these girls in attaining a next higher stage was also computed. The method to record intake of diet and calories had already been described in Part-II study. The pubertal development of these girls at each age was correlated to their caloric intake. This was ascertained by calculating the percentage of different developmental stages of each characteristic separately for the girls consuming adequate and inadequate calories.

Results

Details of the onset of various secondary sex characters are given in *Table I*. No pubertal development was observed below age 8. The breast development appeared first at age 8 in upper socio-economic status girls. All the sexual characters appeared a year or two earlier in USES than LSES girls. In each age group, lesser number of girls from LSES had attained development of either breast or pubic hair or axillary hair or menarche compared to the USES girls.

The ages at the onset of various developmental stages of various secondary sex characters of USES and LSES are shown in *Figs. 1 & 2*. Mean ages (50th percentile)

TABLE I—*Onset of Secondary Sex Characters in Relation to Age*

Age in years	Breast (%)	Pubic hair (%)	Axillary hair (%)	Menarche (%)
USES				
8 - 9(52)	2.1	2.0	-	-
9-10(49)	16.3	8.2	14.2	-
10-11(56)	59.9	51.8	19.6	5.4
11-12(46)	82.6	60.9	39.1	17.4
12-13(41)	95.1	88.1	80.5	56.1
13-14(50)	100.0	100.0	98.0	80.0
14-15(49)	100.0	100.0	100.0	95.5
15-16(21)	100.0	100.0	100.0	100.0
LSES				
8 - 9(49)	-	-	-	-
9-10(40)	-	-	-	-
10-11(49)	32.6	24.5	8.2	-
11-12(49)	57.0	46.8	24.5	8.2
12-13(40)	92.5	70.0	37.5	20.0
13-14(42)	97.5	80.0	42.5	57.7
14-15(47)	100.0	100.0	75.5	81.7
15-16(30)	100.0	100.0	73.6	96.6

A - Appeared
Results are expressed in per cent.
Figures in parentheses are the number of subjects studied.

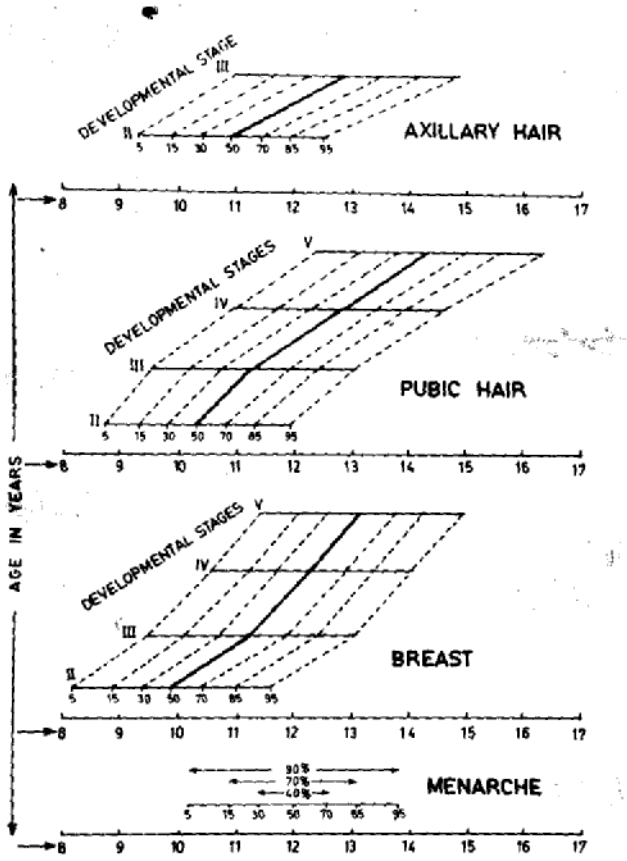

Fig. 1. Percentile grid of menarche, breast, pubic hair and axillary hair developmental stages in USES girls.

for the onset of each secondary sex characters are indicated with thick dotted lines and the growth frequencies are shown in thin dotted lines (between 5-95%). The probability of attainment of any stage at certain age could be determined from the percentile girls.

As evident from the figures, mean age of onset of breast, pubic hair and axillary hair in USES girls was 9.9±1.0; 10.3±1.0 and 10.9±1.1. years, respectively and same in low SES girls were 10.6±1.1; 11.1±1.1 and 12.7±1.1 years, respectively. Mean ages at the onset of breast, pubic hair and of axillary hair were significantly earlier ($p < 0.01$) in USES girls. Mean ages for development stages III, IV and V of breast in USES girls were 11.4, 12.3 and 13.2 years and same in LSES girls were 11.9, 12.8 and 13.5 years. For pubic hair, these were at ages 11.3, 12.7 and 14.4 years in USES girls and at ages 12.9, 14.9 and 15.6 years in LSES girls (*Figs. 1 & 2*).

Centile grid for breast development in USES girls show that atleast 5% of girls would develop Stage II (*i.e.,* onset of breast) by age 8.25 years, Stage III by 9.6 years; Stage IV by the age of 10.4 years and Stage V by 11.4 years (*Fig. 1*). The other end of continuum showed that 95% of the girls would attain Stage II by 11.6 years, Stage III by 13.2 years; Stage IV by 14.2 years and the Stage V (mature breast of adult size) by the age 15 years. Beyond, these girls showing the sign of breast development may be considered as either too early or late in their pubertal growth. Girls from low SES showed the first sign of breast development 0.8 years later than the USES girls (*Fig. 2*). However, thereafter they showed a rapid development with only a marginal difference of 0.3 years at Stage V. After a period of slow growth from Stage II-III, breast growth hastened up during Stages III-IV and IV-V in LSES girls. Both the socio-economic group girls took nearly 3 years for complete breast development.

Pubic and axillary hair development followed a pattern similar to that of breast (*Figs. 1 & 2*). However, axillary hair appeared approximately 12 months and 25 months later in USES and LSES girls, respectively than the onset of breast development. Pubic hair appeared nearly after 6 months later in both SES girls. In both SES girls, complete development of pubic hair took nearly 3-4 years and axillary hair 2-3 years. Pubic and axillary hair maintained a steady rate of growth throughout the period of development.

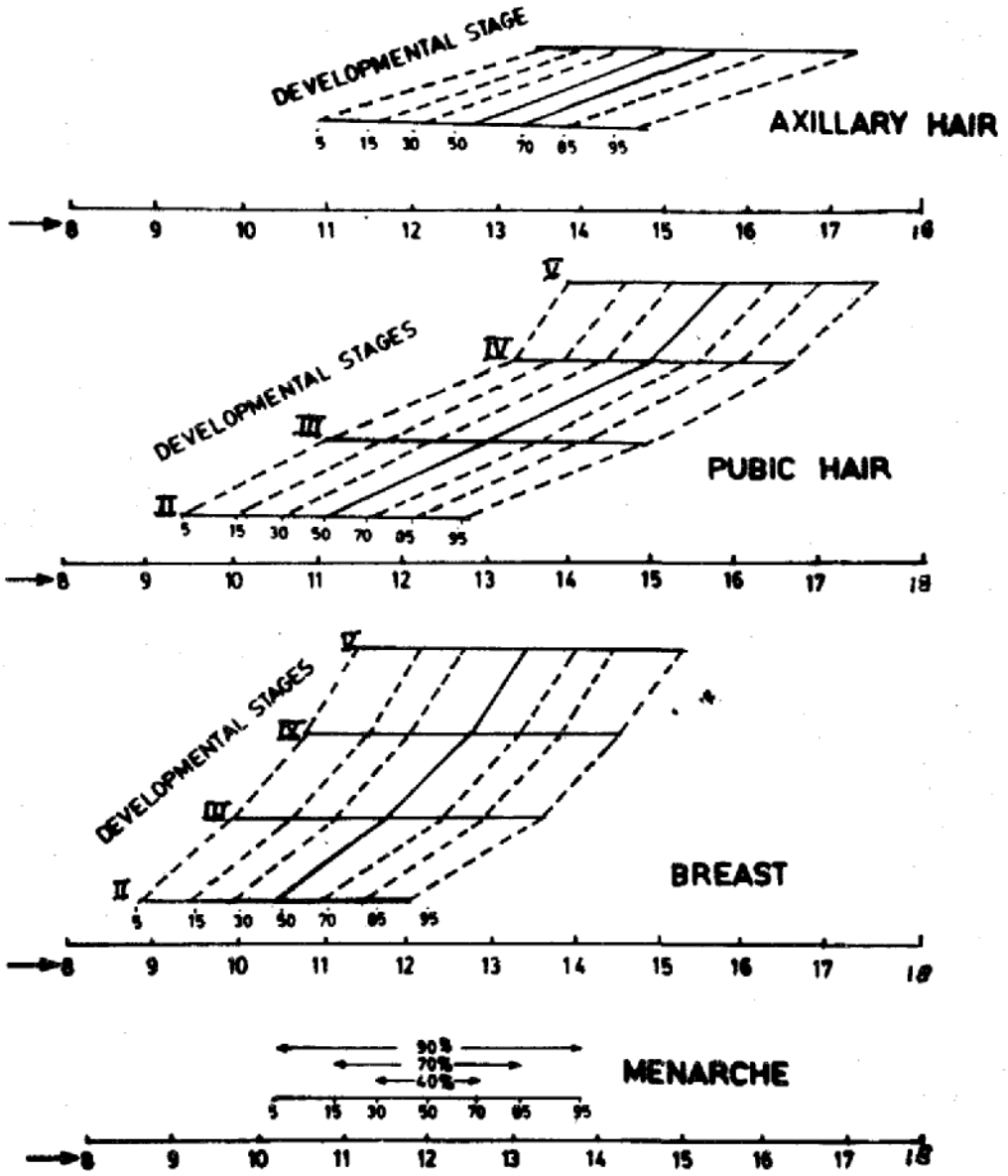

Fig. 2. Percentile grid of menarche, breast, pubic hair and axillary hair developmental stages in LSES girls.

Mean age of menarche was 12.0±1.1 years for upper SES girls and 12.8±1.1 years for low SES and this difference was statistically significant ($p < 0.01$). Ninety five per cent of USES girls attained menarche by 13.8 years and LSES girls by 14.6 years of age (*Figs 1 and 2*).

Variation in attaining development stages

Girls irrespective of SES generally took 0.6-0.9 years to transit a sexual development stage except for axillary hair (*Table II*). Girls took more time to attain Stage III from Stage II compared to attain Stage IV or V. The length of time gradually reduced as a sex-character approached maturity. During the entire period of study 12% girls showed no progress in their pubertal growth. Twelve girls (8 LSES and 4 USES) had unilateral development of breast and

TABLE II—*Transit Time (Years) From a Lower to Higher Developmental Stage of Sexual Maturation*

Developmental stages	Breast		Pubic hair		Axillary hair	
	USES	LSES	USES	LSES	USES	LSES
II - III	0.72	0.72	0.95	0.75	1.02	1.00
III - IV	0.58	0.68	0.67	0.75	-	-
IV - V	0.61	0.63	0.70	0.72	-	-

about an equal number of girls had shown unequal development in two breasts.

Relationship between sex characteristics

The correlation between the various sex characteristics and menarche are presented in *Table III* and were calculated using original values by contingency co-efficient method. The matrix represents the values of correlation for USES in the right upper half and for LSES in the left lower half of the Table.

There was a significant positive correlation in 4 parameters, *viz.*, breast, pubic hair, axillary hair and menarche in both SES group. Menarche correlated better with breast development than pubic or axillary hair. Breast correlated highly with pubic hair irrespective of socio-economic status than the axillary hair developmental stages.

TABLE III—*Correlation Matrix (Contingency Method) for Various Secondary Sex Characters (Upper Socio-economic status)*

Sex character	Breast	Pubic hair	Axillary hair	Menarche
Breast	1.00	0.67	0.62	0.61
Pubic hair	0.60	1.00	0.65	0.53
Axillary hair	0.51	0.60	1.00	0.51
Menarche	0.58	0.49	0.45	1.00

Low socio-economic status.
All the above values are significant ($p < 0.01$).

Relationship of caloric intake with pubertal growth

The girls consuming adequate calories had shown the first sign of breast development in the age group 8-9 years (*Table IV*) while those on inadequate calories, it was between 9-10 years of age. The girls consuming adequate calories showed onset of breast and subsequent developmental stages relatively higher at each chronological age compared to those girls who were on inadequate intake of calories.

Similarly, the girls on adequate calories showed early onset of menarche. The higher percentage of girls at each age with adequate intake of calories attained menarche compared to those who were on adequate diet (*Table IV*).

Likewise the breast, the first appearance of pubic hair was also one-year early in girls with adequate consumption of calories/day while it was not found in case of appearance of axillary hair. However, the subsequent developmental stages did not show any significant relationship with the intake of calories. Girls on inadequate calories between 11-12 years indicated

TABLE IV–*Relation of Calories with the Stages of Pubertal Growth*

Age in years		Developmental stages of breast (%)					Menarche (%)	
		I	II	III	IV	V	I	II
8-9	In (61)	100.0	100.0	–	–	–	–	–
	A (40)	98.5	2.5	–	–	–	–	–
9-10	In (47)	93.6	6.4	–	–	–	99.6	0.4
	A (42)	90.5	9.5	–	–	–	99.4	0.6
10-11	In (79)	62.0	30.4	5.1	2.5	–	98.5	1.5
	A (26)	42.3	42.3	11.5	3.9	–	95.8	4.2
11-12	In (75)	41.4	30.0	12.0	5.3	5.3	87.9	12.1
	A (20)	20.0	40.0	15.0	15.0	10.0	76.9	23.1
12-13	In (64)	9.3	42.2	18.8	21.9	7.8	74.8	25.2
	A (17)	7.6	21.8	28.8	31.8	13.3	35.0	45.2
13-14	In (64)	3.2	32.8	32.8	25.0	6.2	66.4	33.6
	A (28)	–	14.3	35.7	39.3	10.7	25.9	74.1
14-15	In (66)	17.2	2.2	–	6.3	73.9	48.2	51.8
	A (30)	–	–	–	20.0	80.0	10.1	89.9
15-16	In (46)	2.1	4.5	18.8	36.5	38.1	30.1	69.9
	A (5)	–	3.3	13.3	30.0	52.1	–	100.0

* Figures given in parentheses show the number of subjects in each group.
In = Inadequate calories; A = Adequate calories; I = No stage.

early development of adult size of pubic hair (*Table V*).

Discussion

The adolescent growth is remarkable not only on account of the dramatic physical events but equally characteristic sexual development that takes place hand in hand. The sexual development transforms an immature child to mature adult capable of procreation. In the female, sexual development can be objectively and accurately measured followed by the development of secondary sex characters such as breast, pubic hair and axillary hair. The maturity of internal sex organs is marked by the onset of menarche which provides a definite landmark in females.

The secondary sex characters were noted to follow a general pattern in the present study. The first change noticed was the onset of breast development at 8.25 years and by 11.6 years, 95% of the girls had attained this milestone. This was followed by the appearance of pubic hair nearly 0.4 years later and one year later the axillary hair appeared. The end point of development of each stage was not always easy to fix. However, the breast, pubic hair and the axillary hair had fully developed by the age of 15, 16.4 and 15 years, respectively. The girls from LSES had a significant delayed onset of all the three secon-

TABLE V—*Relation of Calories With the Stages of Pubertal Growth*

Age in years	Developmental stages of pubic hair (%)					Axillary hair (%)		
	I	II	III	IV	V	I	II	III
8-9 In (61)	100.0	--	--	--	--	100.0	--	--
A (40)	100.0	--	--	--	--	100.0	--	--
9-10 In (47)	100.0	--	--	--	--	97.9	2.1	--
A (42)	90.5	9.9	--	--	--	90.5	9.5	--
10-11 In (79)	69.5	16.6	3.9	--	--	91.1	8.7	--
A (26)	69.3	19.2	11.5	--	--	88.5	11.5	--
11-12 In (75)	51.9	26.7	16.0	2.7	2.7	74.7	75.3	--
A (20)	45.0	40.0	10.0	5.0	--	70.0	25.0	5.0
12-13 In (64)	43.6	20.8	20.6	17.2	--	37.9	46.9	15.2
A (17)	23.5	23.5	47.1	5.9	--	41.1	47.1	11.8
13-14 In (64)	17.2	20.3	31.2	21.9	9.4	42.2	31.2	26.3
A (28)	14.3	7.1	25.0	42.9	10.7	3.6	46.4	50.5
14-15 In (66)	17.4	8.7	23.9	32.6	17.4	28.7	32.2	39.1
A (30)	--	--	--	--	100.0	--	--	100.0
15-16 In (46)	9.8	10.2	25.2	24.8	30.0	30.5	31.5	38.0
A (5)	6.7	--	13.3	50.0	40.0	19.8	13.3	66.7

* Figures given in parenthesis shown the number of subjects in each group.
In = Inadequate calories; A = Adequate calories; I = No stage.

dary sex characteristics by 0.8-1.8 years. The completion was achieved for the breast, pubic hair and axillary hair in LSES girls by 15.3, 17.6 and 17.6 years of age, respectively. The complete development took nearly 3-4 years. However, girls of LSES completed their breast development comparatively at a faster pace than USES girls.

Indirabai and Vijayalaxmi (6) reported that the mean ages at the onset of breast, pubic hair and of axillary hair were 10.25 10.50 and 13.6 years respectively in South Indian girls while Bhargava *et al.*(12) reported 9.2, 9.9 and 10.6 years, respectively for Delhi children (*Table VI*) The mean ages of breast and pubic hair development in American girls(13) were 10.8 and 11.6 years, respectively and in British girls(2) these were 11.15 and 11.69 years. These studies suggested a finding consistent with the present study that pubic hair normally made their appearance within 6 months of the onset of breast development while axillary hair appearance do not follow any set pattern. It is also evident that Indian girls are ahead in their sexual development (*Table IV*). Significant earlier development of sex characters in USES girls than LSES girls has been recorded by many workers (6,14-17).

A detailed examination of the attainment of each stage of development for each sex characteristic further revealed that Indian girls took less time to reach

TABLE VI—*Ages at the Onset of Secondary Sex Characters in Various Population*

Authors	Population	Onset of		
		Breast	Pubic hair	Axillary hair
Reyonolds and Wines (1948)	American	10.8	11.6	–
Marshall and Tander (1989)	British	11.1	11.7	–
Indirabai and Vijaylaxmi (1973)	South India	10.2	10.5	10.6
Bhargava *et al.* (1980)	Delhi	9.2	9.9	10.6
Present study	North West India	10.6	11.1	12.7

Stage V from IV as compared to British girls. A similar observation has been also made by Kaul *et al.*(18). Thus, like physical growth, sexual growth also completed earlier in Indians than in Britishers or Americans. The sequence of development of sex characteristics did not conform to the general pattern in all the subjects. Such deviation could result from individual variations in the complicated process of development. The development of secondary sex characters is dependent upon the hormonal changes on one side and the end organ response on the other. Generally, the hormonal events move hand in hand with the development of pubic and axillary hair and the breast. The variations in the end organ response could be responsible for variations in the development of secondary sex characters. Similar variations have been reported by earlier workers (1,6,14-21).

The most frequently observed variations were in relations to the breast development and pubic hair. Five per cent of the girls in the present study had developed pubic hair prior to the breast development. Only two girls developed axillary hair prior to either breast or pubic hair. Eveleth and Tanner(21) had reviewed the international literature and calculated that approximately 5% of the girls developed pubic hair earlier than the breast. The other deviation observed with some frequency (2-3%) was in regard to the breast development which proceeded even upto the Stage IV without the appearance of pubic or axillary hair. Such observation has also been made by others(6,13).

The appearance of axillary hair was found to be most inconsistent. These may appear even two or three years after the pubic hair or occasionally precede it. This has been noted earlier also(1,6).

In the present study, unilateral development of breast was observed in 12 girls and about the same number of girls had been observed to have asymmetric growth of the breast. Twelve per cent of the girls did not show any progress in their development stage in any of the secondary sex characters during the study period.

The attainment of menarche was at age 12 years in the USES and in the LSES girls, it was 12.8 years. This difference was statistically significant. The delay of 0.8 years was similar to the one noticed in the development of secondary sex characters. Similar observations have been reported by other workers also(1,6,13,14,16,17,22). A few workers had reported no effect of SES at the onset of menarche(23-26).

The temporal relationship of develop-

ment of secondary sex characteristics and internal sex organ is best appreciated by a correlation of onset of menarche with the stages of breast and pubic hair. The onset of menarche coincided with the breast developmental stage III and IV. It also correlated with the same stage of pubic hair development. The correlation of axillary hair to menarche was not consistent. Similar observations have been recorded by Tanner(1). The same relation was maintained in the girls from LSES though these girls were chronologically 0.8 years older than USES. A significant high correlation among these sex characters has been reported earlier by several workers (6,12,13,27,28).

The present observation thus led us to conclude that attainment of puberty is under the control of biological clock but its onset is influenced strongly by the exogenic factors.

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