

Menarche and voice change as indicators of the pubertal growth spurt

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Longitudinal data on adolescent growth in body height and on the occurrence of menarche in girls and voice change in boys have been collected as part of a prospective study of the growth and development of 212 randomly selected Swedish urban children. The onset, peak and end of the pubertal growth spurt was defined on the unsmoothed incremental curve of height. The relationship in time between these events and menarche and voice changes was studied.

Menarche occurred between 10.7 and 16.1 years (mean 13.1 years, S.D. = 1.09). No menstrual bleeding occurred before peak height velocity and all girls had the menarche before the end of the spurt. Clinically assessed voice change began between 11.5 and 16.5 years (mean 13.9 years, S.D. = 1.03). A voice with adult characteristics was observed between 12.5 and 17.5 years (mean 15.0 years, S.D. = 0.98). The duration of the voice change varied between less than one year and more than three years. When the voice change of a boy has begun, the growth spurt is in its most intensive phase. When the voice has acquired adult characteristics the growth rate has begun to decelerate.

Key-words: Maturity indicators; orthodontic treatment timing; puberty

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The pubertal growth spurt is an advantageous period for orthodontic treatment (3, 10, 11). The individual age at which the spurt occurs varies greatly (26, 37). It is therefore essential to determine whether the pubertal spurt has been passed or not. Longitudinal growth records of body height can be used in treatment planning since there is a close association between the growth spurt in body height and facial dimension (3, 38). However, in clinical contexts longitudinal growth records are seldom available. The clinician must usually base his judgement on single examinations. The growth status of

an individual must accordingly often be evaluated by a cross-sectional approach (27).

In such situations additional information on the physical maturity of an individual can be obtained from his or her skeletal and pubertal development by determining whether a certain maturity indicator has been attained or not.

In a previous paper we analysed adolescent growth in body height in 212 Swedish urban children (37). The occurrence of some skeletal stages of the hand and wrist and their relation to the pubertal growth spurt have also been reported

(15). In addition, data on the somatic pubertal development of the same children have been published (36).

The aims of this paper were:

- to determine the timing of the menarche and voice change in a representative prospective longitudinal sample of Swedish girls and boys, and
- to describe the relation in time between these pubertal events and the pubertal growth spurt.

Menarche and voice change have been chosen as maturity indicators of pubertal development since in orthodontics one has to use indicators which do not require a physical examination.

MATERIAL AND METHODS

Data on pubertal development and body height were collected from 212 randomly selected Swedish urban children (90 girls and 122 boys) as part of a prospective longitudinal study of growth and development from birth to adulthood (17, 18). The children were born between 1955 and 1958. The method of selection and representativeness of the subjects have been discussed in previous reports (17, 18). During the age period covered by this paper the subjects were examined once a year up to the age of 18 and also at the age of 20–22. From 10 years onwards the girls were asked every three months whether or not menstrual bleeding had occurred. In boys the voice was assessed annually from the same age.

Height was measured with the stretching up technique according to the method suggested by Tanner (40). The onset (ONSET), peak (PHV) and end (END) of the spurt were established on the unsmoothed incremental curve (Fig. 1) (37).

Assessment of the voice was done clinically, i.e. by a combination of the examiner's opinion of the voice when the boy talked and read during the examina-

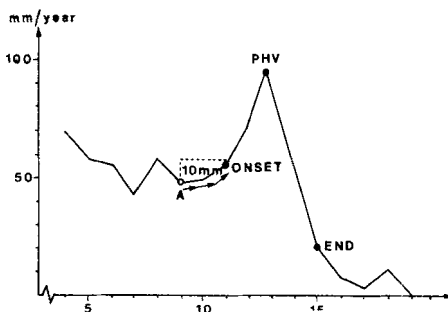


Fig. 1. The pubertal growth spurt.

Onset of the spurt (ONSET) is the smallest annual increment from which there is a marked continuous increase in growth rate to PHV. ONSET is found by locating the smallest annual increment (A) from which there is a continuous increase in growth rate to PHV. The curve is then followed towards PHV until the growth rate has accelerated 10 mm. ONSET will be represented by the annual increment which is next below or coincides with this growth rate.

Peak height velocity (PHV) is the greatest annual increment during puberty.

The end of the spurt (END) is the first annual increment after PHV below 20 mm.

tion and of the subject's own reports of highpitched voice breaks or other voice changes. Assessment of the voice was done without knowledge of the previous ratings. Three stages of voice change were used: 1. prepubertal voice (the pitch of the voice had not changed noticeably); 2. pubertal voice (the pitch of the voice had changed noticeably but the voice had not yet required adult characteristics); 3. male voice (the pitch of the voice had adult characteristics).

During puberty there is a rapid growth of the larynx in boys, with associated change in its form (31). The voice changes in quality and drops about one octave in pitch (17). In most boys the pubertal change starts with a certain huskiness of the speaking voice. A real breaking of the voice occurs only in a few boys (41).

From the time prior to the pubertal spurt 92.5% of the original 212 subjects were regularly followed. At the end of the spurt 86.3% of the subjects remained in the study.

Table 1. Probit analysis of the age (in years) at attainment of various adolescent maturity indicators in girls and boys

Event	Sex	Mean	S.D.	Adjustment of probit line Chi ²	df	Range
Pubertal spurt ONSET	G	10.04	1.26	3.03	7	6.5-13.5
	B	12.08	1.20	3.83	8	9.5-15.5
PHV	G	11.98	1.02	9.41	6	9.5-15.5
	B	14.07	1.08	2.53	6	11.5-17.5
END	G	14.82	0.88	1.19	5	13.5-17.5
	B	17.05	0.98	1.32	5	14.5-19.5
Menarche	G	13.08	1.11	2.98	6	10.7-16.1
Pubertal voice	B	13.90	0.95	2.49	5	11.5-16.5
Male voice	B	15.02	0.91	0.52	4	12.5-17.5

No value of Chi² is statistically significant (p < 0.10)

At ten years, the last examination at which menarche had not yet occurred in any girl, 81 girls still participated in the study. Only one of these girls left the study before menarche had occurred. At the last examination this girl was 12 years old. The exact age of menarche was known in 73 out of 80 girls. In the remaining seven girls the month of menarche was known.

At eleven years, the last examination at which all boys had a prepubertal voice, 106 (80.9%) boys still participated in the study. Four of these boys left the study before any change of the voice occurred, the oldest being 14 years at the last examination. The annual interval during which the pubertal voice and the male voice was attained was known in 98 and 91 boys, respectively.

Statistical methods

The age of a boy at the attainment of a certain voice stage was defined as the midpoint of the age interval during which the change occurred. When there was a two-stage change, e.g. from a pre-

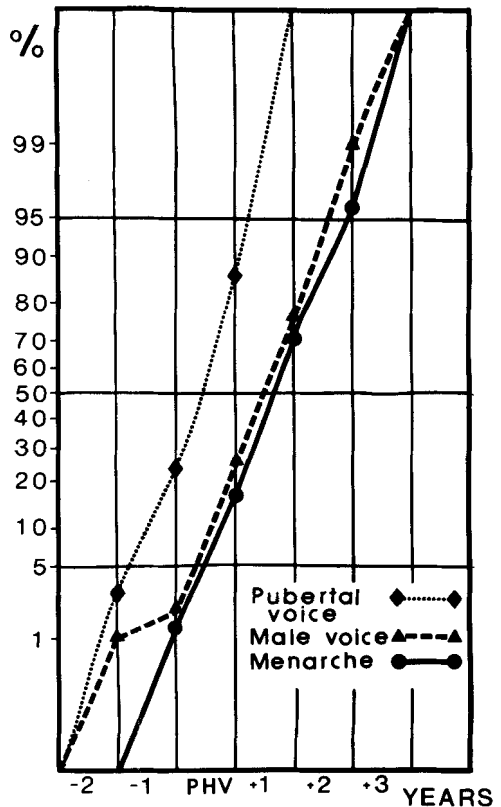


Fig. 2. Distributions (in cumulative percentage) by age at menarche, at pubertal voice and at male voice in relation to the year of peak height velocity (PHV).

pubertal voice to a male voice, the interval between two examinations was divided into three equal parts. The individual ages of the voice stages and the menarche were used in the correlation analysis. The mean ages at the occurrence of the menarche and the voice stages were calculated by probit analysis (8). In this analysis maximum information was extracted from the sample according to the principles described earlier (35), which will give an unbiased estimate of the mean values (33).

The cumulative percentages were calculated from the raw figures of the probit analysis (Tables 2, 4, 5 and Fig. 2).

RESULTS

The mean and variance of the ages at menarche, voice stages and the pubertal growth spurt are given in Table I. The cumulative percentages of children who had attained a certain pubertal event in each age interval are given in Table 2. The correlation coefficients between the occurrence of menarche and voice stages and the pubertal growth spurt are given in Table 3. The relation in time between menarche and voice stages and the peak height velocity (PHV) and of the end of the spurt (END) respectively are given in Tables 4, 5 and Fig. 2.

On an average, the pubertal growth spurt began (ONSET) at the age of about 10 years in girls and 12 years in boys. In both sexes PHV occurred about two years after the onset of the spurt. The end of the pubertal spurt (END) was attained at the age of about 15 in girls and 17 in boys (Table 1).

The youngest age at menarche was 10.7 years, while the last girl had the menarche at 16.1 years. At the age of 13 years the menarche had occurred in half of the girls.

A change in the voice (pubertal voice)

was registered between 11.5 and 16.5 years. The voice became noticeably adult in quality (male voice) between 12.5 and 17.5 years. In 19 out of 100 boys the change from a prepubertal voice to a male voice occurred between two consecutive annual examinations. In three boys a pubertal voice was recorded at three consecutive examinations. Thus the duration of the voice change varied from less than one year to about three years. On an average, the menarche occurred 1.1 years after PHV and 1.8 years before the end of the spurt (END). The correlation coefficients were 0.77 and 0.76, respectively (Table 3). One girl out of 80 experienced a bleeding in the annual interval preceding PHV (Table 4, Fig. 2). In 13 girls the menarche was recorded in the same annual interval as PHV. In three girls the menstrual bleedings did not start until the third annual interval after PHV. At the end of the spurt (END) all girls had begun to menstruate. In 4 out of 80 the menarche was registered in the same interval as the end of the spurt (Table 5).

Voice change began, on an average, 1.8 years after the onset of the spurt (ONSET). The correlation coefficient was 0.64. In one out of 100 boys the voice change occurred in the annual interval preceding ONSET.

On an average the pubertal voice was attained 0.2 years before PHV. The correlation coefficient was 0.82. In 60 out of 98 boys the voice change began in the interval with the greatest annual increment (PHV) (Table 4, Fig. 2). A male voice was observed before PHV in only 2 out of 91 boys (Table 4, Fig. 2). On an average, a male voice was recorded 0.9 years after PHV and 2.0 years before the end of the spurt (END). At END all boys had a male voice. In one boy the male voice was acquired in the same annual interval as the end of the spurt occurred. No reversals of voice stages were recorded among 891 assessments made on 106 boys.

Table 2. Cumulative percentage of girls and boys who had attained various adolescent maturity indicators at the end of each age interval

Age interval in years	ONSET		Pubertal spurt PHV		END		Menarche	Pubertal voice	Male voice
	G	B	G	B	G	B	G	B	B
6 - 7	1.2								
7 - 8	3.7								
8 - 9	21.0								
9 - 10	49.4	5.3	1.2						
10 - 11	79.0	14.7	19.8				1.2		
11 - 12	95.1	51.4	46.9	1.9			17.3	0.9	
12 - 13	97.5	79.4	88.8	15.2	1.2		48.8	20.2	1.0
13 - 14	100.0	92.5	97.5	50.5	17.3		80.0 ^a	54.4	13.0
14 - 15		99.1	98.7	81.9	61.7	1.0	95.0	83.5	51.0
15 - 16		100.0	100.0	96.1	90.1	15.2	98.8	99.0	85.4
16 - 17				99.0	98.8	50.5	100.0	100.0	98.0
17 - 18				100.0	100.0	81.9			100.0
18 - 19						97.1			
19 - 20						100.0			

^aOne girl had a break-through bleeding of unknown etiology at 11.7 years of age. This girl had the menarche at 13.3 years of age, see text.

Table 3. Correlation coefficients between age at the occurrence of various maturity indicators in girls (N = 79-80) and boys (N = 91-98)

Event	Sex	ONSET	Pubertal spurt PHV	END
Menarche	G	.60	.77	.76
Pubertal voice	B	.64	.82	.78
Male voice	B	.55	.73	.75

Table 4. Cumulative percentage of girls and boys having attained the menarche or a certain stage of voice change at the end of each annual interval in relation to the interval during which the peak height velocity (PHV) occurred

Age interval to PHV	GIRLS Menarche	BOYS Pubertal voice	Male voice
-2		2.9	1.0
-1		23.5	2.0
PHV	16.3	86.1	25.0
+1	71.3 ^a	100.0	76.8
+1	96.3		99.0
+3	100.0		100.0

^aOne girl had a break-through bleeding of unknown etiology during the annual interval before PHV, see text.

DISCUSSION

Menarche

The occurrence of menarche in the present study agreed well with other contemporary Scandinavian studies (1, 6, 9, 16, 21, 23). As concerns the relationship between the menarche and the pubertal growth spurt, it has been stated that the menarche does not occur until PHV has been reached or passed (4, 24, 25). In this study one out of 80 girls had a bleeding before PHV, but this was probably a break-through bleeding of unknown etiology and not the ordinary menarche (5). The first bleeding of this girl occurred at 11.7 years but at 12 years there was no sign of puberty except slight development of the breasts. PHV was reached at 12.5 years, while the next bleeding did not occur until the age of 13.3 years. In another Swedish study it was reported that the menarche occurred before PHV in less than 2% of the subjects, i.e. 6 out of 357 subjects (20, 22). However, the only one of these girls for whom the puberty rating is known (20) still had infantile sex characteristics when the first bleeding occurred. Accordingly, these girls may also have had break-through bleedings, and not the ordinary menarche, at the time of registration of menarche.

Since puberty ratings cannot be performed in orthodontic practice, the anamnestic data on menarche cannot be validated in a comparison with other signs of puberty. Consequently, if girls are merely asked if and when the menarche has occurred, occasional girls can be expected to have had a «menstrual» bleeding before PHV. Furthermore, some girls, especially if having a comparatively early or late menarche, will give inaccurate or false answers when questioned about the occurrence of the menarche (2, 26). This may complicate further evaluation of the menarche in the clinical situation, but the problem may be

Table 5. Cumulative percentage of girls and boys having attained the menarche or a male voice at the end of each annual interval in relation to the interval during which the end of the spurt (END) occurred

Age interval to END	GIRLS Menarche	BOYS Male voice
-4		2.0
-3	15.0	26.0
-2	58.8 ^a	74.5
-1	95.0	99.0
END	100.0	100.0

^aOne girl had a break-through bleeding of unknown etiology during the fourth annual interval before END, see text.

avoided if the examiner is observant and puts the questions in a psychologically appropriate way.

Voice change

Three methods for assessment of the pubertal change of the voice have been described: 1 anamnestic data (32), 2 clinical assessment (1, 13, 28, 29, 30) and 3 technical analysis of vocal frequency characteristics (7, 14, 39). In this study clinical assessment has been used and the timing of the voice change was in agreement with cross-sectional studies using anamnestic data or clinical assessment (1, 13, 28, 29, 30, 32). Since the study was a longitudinal one, the duration of the voice change could also be analysed. The change from a prepubertal to a male voice took from less than one year to more than three years and took place between 11 and 18 years. In a study using technical analysis of the vocal frequencies, it was reported that «analysis of individual trends indicate that pubescent voice change may take as little as a few months or as long as several years to complete, and that it may be initiated (at least) as early as 12 years of age or (at least) as late as 15 years of age» (14).

Some investigators have found it difficult to evaluate voice changes objectively

by clinical assessment (12, 34), but no cross-validation of the various methods has been published. No formal assessment of the methodological error was made in the present study, but no reversals of voice stages were recorded at the annual examinations from the age of 10 years to 18 years. Technical analysis of the vocal frequencies should be more informative and reliable than the other methods. However, this technical analysis has so far been extremely time-consuming (14) and reported studies have therefore comprised very small samples (7, 14, 39). Recently new devices for electronic analysis of the voice which are not time-consuming and are well suited to research purposes have become available (19, 43). This equipment will no doubt be used in clinical work in the near future.

A consistent pattern of the relation between voice changes and the pubertal growth spurt was found (Tables 5, 6, Fig. 2). Only one out of 106 boys had a pubertal voice before the onset of the spurt. This boy was one of the three in whom a pubertal voice was registered at three consecutive examinations. In all subjects the voice change had begun during the annual interval following PHV. Only two out of 100 subjects had a male voice before PHV. These two boys had a very late occurrence of PHV, at 16.5 and 17.5 years respectively. However, when the male voice was observed for the first time the testicular volume was estimated to be 20 and 15 ml respectively. Accordingly, the testosterone production ought to have given the larynx adult characteristics (42). Male voice was not recorded until the end of the spurt in one out of 99 subjects. This boy was one of the three with a pubertal voice at three consecutive examinations.

This descriptive analysis can be used to facilitate evaluation of individual growth and maturation. Although this approach does not give statistically calculated confidence limits of the relations, it is still

useful in the clinical situation. A more comprehensive picture of the individual maturity level will be obtained, and decisions as when to start or end a certain treatment will be made in a more systematic way.

CONCLUSIONS

The following findings were made concerning the relationship in time between the various pubertal events:

Girls

- If the menarche has occurred, peak height velocity (PHV) has been attained and the growth rate is decelerating.
- If the menarche has not occurred, the growth rate may be decreasing but has certainly not yet reached the level of the end of the pubertal growth spurt (20 mm per year).

Boys

- If a boy has a prepubertal voice, it is most probable that the peak height velocity has not yet been reached.
- If the voice change has begun, the boy is in the pubertal spurt.
- If a boy has a male voice, the growth rate has begun to decelerate.
- No boy will reach the end of the pubertal spurt without having a male voice.

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