Pubertal Spurts in Cranial Base and Mandible

Comparisons Within Individuals

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Examination of median growth increments in cranial base and mandibular dimensions finds pubertal growth spurts tending to closely follow peak height velocity and the appearance of the ulnar sesamoid.

KEY WORDS • GROWTH • PUBERTAL GROWTH SPURT •

Previous studies, including those based on most of the children included in the present investigation, have shown that pubertal spurts occur in the growth of the cranial base and mandible of most children (NANDA 1955 AND 1956, BAMBHA 1961, LUKS 1969, PILESKI ET AL. 1973, ROCHE AND LEWIS 1974, BAUGHAN ET AL. 1979, LEWIS ET AL. 1982). Variations are great, but there are clear tendencies for the spurts in both cranial base and mandible to occur later in boys than in girls. Growth spurts also appear to be larger in boys than in girls, except in the cranial base dimensions Ba–S and S–N.

Although there has been considerable interest in the pubertal spurts in the craniofacial area, only the reports of NANDA (1955 1956), HUNTER (1966) AND DOLAN (1967) address the sequence of these spurts within individuals. All of these reports are based on data from records of the Child Research Council of Denver.

Clearly, synchrony of growth spurts is desirable from orthodontic and functional viewpoints, particularly in dimensions with similar orientation, such as S–N and Go–Gn. However, growth spurts within the craniofacial area are often asynchronous. Some of this asynchrony could be associated with variations in the timing and size of the pubertal spurts in the cranial base and mandible of the individual.

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The present investigation was undertaken to elicit information about the extent of such variations.

— Material and Methods —

Measurements were made on serial cephalometric radiographs of 34 boys and 33 girls enrolled in the Fels Longitudinal Study for whom suitable sets of radiographs were available. All were white children from middle socioeconomic families living in southwestern Ohio.

The measured radiographs were exposed within one month of birthdays from at least 7 years through 18 years of age. In 64 of the children, individual series extended from at least four years before to four years after the age at peak height velocity (PHV - see below). In two individuals the range was from two years before to two years after PHV. The final radiograph in one boy was taken only 1.75yr after PHV.

Tracings of each radiograph were made by one person, and the measurements by another. Cranial base lengths Ba-N, S-N, and Ba-S were measured with dial calipers. A digitizer was used to record the locations of points Ar, Go, and Gn on the mandibular tracings.

Articulare is defined as the intersection of the images of the posterior margin of the mandibular ramus and the inferior border of the basisphenoid bone. Gonion (Go) is the point on the mandibular border that intersects the bisector of the angle formed by projections of the mandibular plane and posterior border of the ramus. Gnathion (Gn) is the point on the symphysis that similarly intersects the bisector of the angle formed by the mandibular plane and facial line (Lewis et al. 1982).

Precision of both caliper and the digitizer records is 0.1 mm. Repeated measurements of 1054 radiographs showed very small absolute differences between pairs of measurements made with the calipers and pairs measured with the digitizer. Most mean differences were less than 0.2mm. Correlation coefficients between caliper and digitizer measurements were ≥ 0.97 for each age- and sex-specific group.

All measurements were corrected for radiographic enlargement.

Spurts

Spurts (accelerations in the rate of growth) were identified from unsmoothed plots of annual increments (mm/yr). The specific definition of a spurt used in this study is a rate of growth in the cranial base exceeding that in the preceding annual interval by at least 0.75mm for boys and 0.5mm for girls, and in the mandible by 1.0mm for either sex. These values exceed the sex-specific median annual rate of growth by at least 50% (Lewis and Roche 1972 and 1974, Lewis et al. 1982).

Age at each spurt was recorded as the *midpoint* of the annual interval during which the spurt was recorded.

In cases where an annual radiograph was missing, a spurt was recorded for the annual interval immediately following only if that annual increment exceeded the *total two-year increment* by the criterion amount. The two-year increment was *not* apportioned to the two annual intervals.

A few negative annual increments (≤ 0.2mm/year) were recorded. These were assigned a value of zero in calculating the differences between successive increments.

Pubertal Spurts

Spurts occurring within two years of PHV were classified as pubertal. When the criteria for the recognition of spurts were applied to series of annual radiographs, some individuals exhibited more than one spurt during pubescence in one or more dimensions.

The present analysis is based almost entirely on the earliest pubertal spurt for each child, but reference is also made to maximum pubertal spurts. The largest spurt found for each child within two years of PHV was classified as the maximum pubertal spurt, which in most subjects was also the first.

Peak Height Velocity (PHV)

Stature of these children was measured at six-month intervals. The midpoint of the annual interval with the largest increment in stature for each child was recorded as age at peak height velocity (PHV). When two equal consecutive annual increments were also the largest, the midpoint of the combined interval was recorded as PHV.

Skeletal Age

Greulich-Pyle hand/wrist skeletal ages were determined at six-month intervals. These were recorded as the medians of the bone-specific skeletal ages.

Ulnar Sesamoid (US)

Age at onset of ossification in the ulnar sesamoid of the first metacarpophalangeal joint (US) was recorded as the midpoint between the age on the last radiograph in which this bone was not ossified and the age at the first radiograph in which ossification was detected.

Menarche

Age at menarche was determined by inquiring at 6-month intervals during the appropriate age range. The means and standard deviations for the measures of growth and maturity were similar to those from surveys of large representative samples by the National Center for Health Statistics (Hamill et al. 1977, Roche et al. 1974, Roche et al. 1976).

— Findings —

Pubertal spurts in the craniofacial area were very common. In the boys the incidence was greatest for Ba–N, Go–Gn and Ar–Gn. In the girls it was greatest for Ba–N, S–N, and Ba–S (Table 1).

One boy and two girls did not exhibit pubertal spurts meeting the criteria in any of the three cranial base lengths, and one boy and three girls showed no pubertal spurts in the three mandibular dimensions. A considerably higher percentage of boys than girls showed pubertal spurts >1mm for each mandibular length, but there were only slight sex differences in the percentage prevalence of spurts in the cranial base.

The mean age of occurrence of FPS in cranial base dimensions was 1.6yr earlier for females. The considerable overlap between the sexes is indicated by the standard deviations, which ranged from 1.3 to 1.9yr.

The relationship of FPS to maturational events is shown in Table 2. Beginning of spurts tended to precede PHV by about 0.5yr in both sexes, and and it preceded menarche by about 1.5yr. In both boys and girls, mean age at first rise toward the spurt ranged from about 0.6 to 1.3yr after ulnar sesamoid ossification, with the standard deviations indicating a lesser degree of association.

Peak growth rate in the spurt followed both US and FPS.

The mean increment at the time of the FPS was about 25% greater in boys than in girls for each dimension. Correspondingly, the mean size of the FPS in each length (difference between successive annual increments in mm/year) was greater in boys than in girls by about 33%, which is consistent with the spurt criteria (Table 3).

The mean rate of growth during the year immediately preceding the beginning of the spurts was markedly less than the rate during the year succeeding FPS.

Table 1

First Pubertal Spurts
in Cranial Base and Mandibular Length
Prevalence, Age of Occurrence, and Size

Dimension	N	Percentage Prevalence of Spurts	Age at Spurt (years)		Increment at Spurt (mm/yr)		Size of Spurt (mm/yr)	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
S—N	♂ 26	77	13.5	1.5	1.6	0.5	1.3	0.4
	♀ 28	85	11.9	1.4	1.2	0.4	0.9	0.4
Ba—N	♂ 32	94	13.0	1.5	2.6	1.1	2.0	1.1
	♀ 30	91	11.4	1.6	2.0	0.9	1.4	0.8
Ba—S	♂ 25	74	13.2	1.6	2.0	0.8	1.6	0.8
	♀ 27	82	11.6	1.9	1.6	0.8	1.3	0.8
Go—Gn	♂ 30	88	13.2	1.4	2.8	1.2	2.2	1.2
	♀ 22	67	11.3	1.8	2.3	0.8	1.6	0.7
Ar—Go	♂ 25	74	13.5	1.7	3.2	0.9	2.5	0.9
	♀ 18	55	11.8	1.3	2.4	0.8	1.9	0.7
Ar—Gn	♂ 29	85	13.1	1.4	3.3	1.5	2.5	1.4
	♀ 20	61	11.6	1.6	2.9	1.3	1.9	0.9

A Spurt is defined on the basis of the difference between successive annual increments see text for details.

Table 2

Timing of First Pubertal Spurts (years) in relation to
Peak Height Velocity (PHV), Ossification of Ulnar Sesamoid (US), and Menarche (M)

Dimension	N	Relation to PHV Mean	S.D.	Relation to US Mean	S.D.	Relation to M Mean	S.D.
S—N	♂ 26	−0.38	1.2	+1.24	1.6	—	—
	♀ 28	−0.04	1.2	+1.29	1.2	−1.28	1.3
Ba—N	♂ 32	−0.79	1.0	+0.65	1.6	—	—
	♀ 30	−0.48	1.1	+0.84	1.3	−1.70	1.4
Ba—S	♂ 25	−0.54	1.4	+0.86	1.7	—	—
	♀ 27	−0.31	1.4	+1.03	1.6	−1.49	1.5
Go—Gn	♂ 30	−0.67	1.0	+0.88	1.6	—	—
	♀ 22	−0.42	1.4	+0.83	1.6	−1.78	1.5
Ar—Go	♂ 25	−0.21	0.8	+1.26	1.1	—	—
	♀ 18	−0.25	0.8	+1.32	1.3	−1.09	0.9
Ar—Gn	♂ 29	−0.65	1.2	+0.77	1.4	—	—
	♀ 20	−0.42	0.8	+0.84	1.0	−1.47	0.8

This pattern was present in all six dimensions for boys and girls, but there was a tendency for the rate of growth immediately before the spurt to be greater in girls than in boys. Rates of growth during the year of the FPS and the following year were greater in the boys.

Figure 1 shows the median annual increments for each length for boys and girls before and after FPS. The cranial base and mandibular dimensions are paired in this figure on the basis of their general orientations within the craniofacial area. This shows a consistent general pattern of growth in relation to FPS in all dimensions, with similar decelerations noted one to three years before FPS in boys and girls in most dimensions.

Median levels show little growth in most dimensions three and four years after FPS; Ar-Gn in the boys exceeded 1mm/year average growth during the interval from three to four years after FPS. Exceptions were Ar-Go and Go-Gn in boys, and Ba-S in girls, which were near zero.

Comparisons between Ba-N and Ar-Gn show larger decelerations in Ar-Gn before FPS, with more gradual decelerations after. Growth is more rapid in Ar-Gn than in Ba-N before, during and after FPS, and the magnitude of FPS in Ar-Gn is larger in boys than in girls.

When data for S-N and Go-Gn are compared, it is found that decelerations in Go-Gn before FPS are larger in girls, but there is little corresponding difference in boys. In each sex, Go-Gn shows larger increments of growth before, during and after FPS, with larger spurts followed by larger decelerations.

Increments of growth of Ar-Go are larger than those of Ba-S before, during and after FPS in each sex. Decelerations before and after FPS are approximately equal for Ar-Go and Ba-S.

Figure 2 shows median rates of growth plotted in relation to the onset of ossification in the ulnar sesamoid (US), with the increment for the annual interval for the year before US shown on the x-axis at 1-0 and those for the year after at 0-1. A similar convention is used in Fig. 3.

Mandibular decelerations before FPS were slight. The largest median increment during pubescence occurred within two years after US, with the exception of Ba-S in boys and Ar-Gn in the girls, who showed a pattern of gradually decreasing increments from three to four years before US until three to four years after US. Comparison of Figs. 1 and 2 shows that decelerations in median growth and the magnitude of FPS are much less marked in relation to US than to the timing of

Table 3

Mean Annual Increments before, during and after FPS (mm/year)

	1 yr Before		Year of spurt		1 yr after	
	Boys	Girls	Boys	Girls	Boys	Girls
S–N	0.2	0.2	1.6	1.2	0.8	0.5
Ba–N	0.5	0.4	2.6	2.0	1.2	1.0
Ba–S	0.1	0.3	2.0	1.6	0.6	0.4
Go–Gn	0.5	0.6	2.8	2.3	1.2	1.1
Ar–Go	0.2	0.4	3.2	2.4	1.8	1.0
Ar–Gn	0.5	0.9	3.3	2.9	2.6	2.3

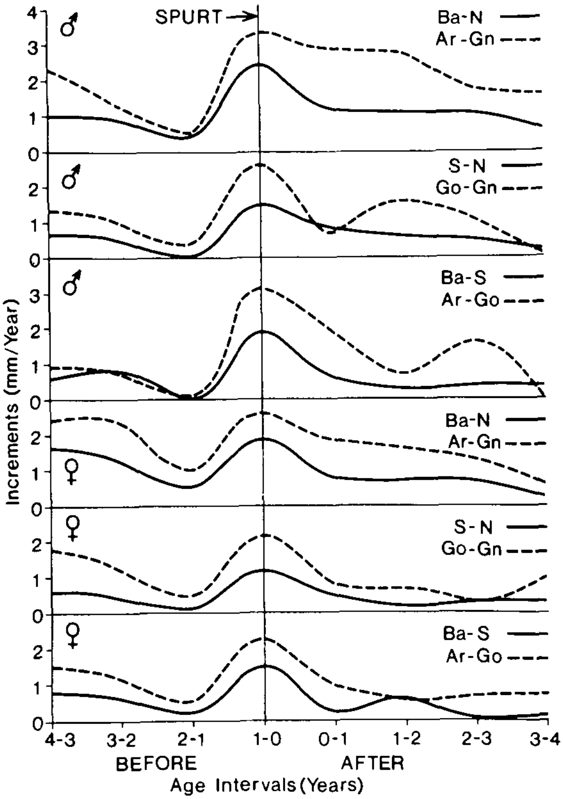

Fig. 1

Median annual increments (mm/yr) in cranial base and mandibular measurements, plotted in relation to the timing of the pubertal spurt in each measurement within individuals

FPS. This indicates a low correlation between the timing of US and FPS.

Corresponding data were calculated for median increments in relation to the time of peak height velocity (PHV). These showed slight decelerations before PHV for a few of the dimensions (Fig. 3). Maximum median increments tended to occur in the year after PHV.

Stature

There are interesting differences between tall and short children in the elongation of the cranial base and mandible. The six tallest and the six shortest boys in the study sample were selected on the basis of their stature at 18 years, when the mean stature for all 34 boys was 179.0cm. Mean stature of the tall boys was 185.3cm, and the short boys 169.1cm.

The total increments after PHV were considerably larger in the short boys than the tall boys for all dimensions except Go–Gn (Table 4). Mean age at PHV was similar for the two groups (tall, 13.7yr;

Table 4

Mean total Increments from Age at Peak Height Velocity to 18 years in Tall and Short boys (millimeters)

Dimension	Tall	Short
S–N	3.68	4.16
Ba–N	4.10	6.44
Ba–S	1.80	3.58
Go–Gn	7.63	6.71
Ar–Go	7.48	8.94
Ar–Gn	11.01	12.41

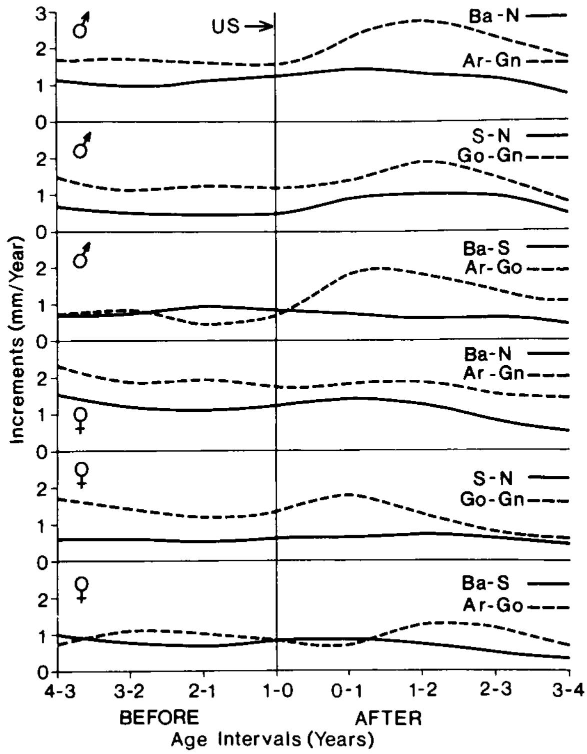

Fig. 2

Median annual increments (mm/yr) in cranial base and mandibular measurements, plotted in relation to the onset of ossification in the ulnar sesamoid (US)

short, 13.5yr). There were no consistent differences between the tall and short boys in the mean increments at FPS.

Comparisons between lengths calculated in relation to US for a tall and a short boy are presented in Fig. 4. The tall boy at 18 years had a stature exceeding the 90th percentile, while at the same age the short boy's stature was below the 5th percentile (Roche et al. 1977). For both boys the time intervals between US and PHV were equal, but these events occurred two years earlier in the short boy. Measurements in Fig. 4 are plotted around US and PHV to remove effects of differences in the chronological ages at which these events occurred.

For all cranial base dimensions, the tall boy had markedly larger values than the short boy at all ages. There were decelerations followed by slight accelerations at or shortly after US for Ba–N and Ba–S in both boys. The differences between the tall and short boy in each cranial base length changed little from 7.5yr before to 2.5yr after US, except for Ba–N in which the difference increased markedly.

For the mandibular dimensions, the tall boy showed larger values than the short boy for Ar–Gn and Go–Gn at all ages, but the differences decreased with age. The data for Ar–Go differed little between the tall and the short boy. Early in the series (6.5yr before US), the values for Ar–Go were almost the same for both boys, but toward the end of the series, Ar–Go in the short boy was slightly larger.

Correlations

Correlations between the ages of occurrence of FPS in all pairs of cranial base and mandibular lengths were consistently higher in girls than boys (Table 5). In the

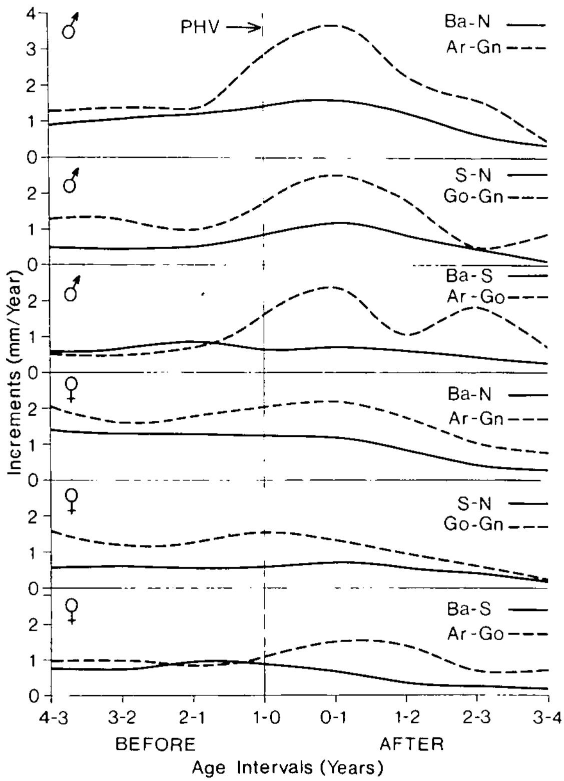

Fig. 3 **Median annual increments (mm/yr) in cranial base and mandibular measurements, plotted in relation to peak height velocity (PHV)**

Table 5

Correlations Between Ages at First Pubertal Spurts in Cranial Base and Mandibular Length

° P<.05 • P<.01

Dimensions	Boys	Girls
Ba–S vs Ar–Go	0.50°	0.70•
Ba–S vs Go–Gn	0.42°	0.48°
Ba–S vs Ar–Gn	0.32	0.60•
Ba–N vs Ar–Go	0.59•	0.81•
Ba–N vs Go–Gn	0.53•	0.68•
Ba–N vs Ar–Gn	0.48°	0.76•
S–N vs Ar–Go	0.62•	0.63•
S–N vs Go–Gn	0.49°	0.61•
S–N vs Ar–Gn	0.28	0.56°

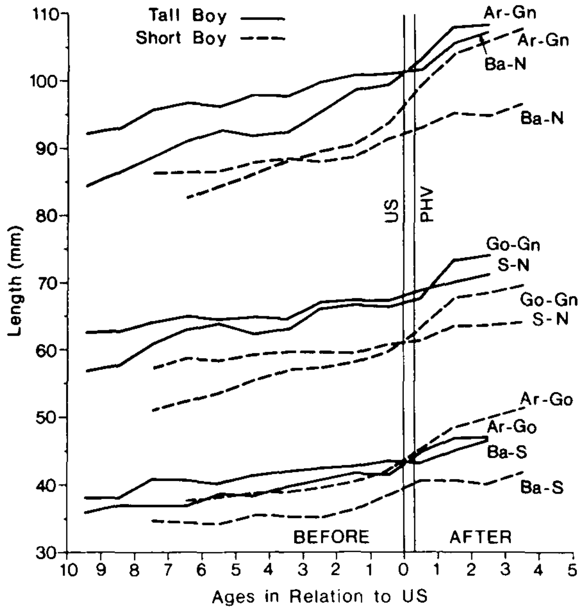

Fig. 4 Serial cranial base and mandibular lengths (mm) in a tall boy and a short boy, plotted in relation to the onset of ossification in the ulnar sesamoid (US) and age at peak height velocity (PHV)

boys, correlations with Ar–Gn tended to be lower than those with the other mandibular lengths, but there was no corresponding tendency in the girls. Nevertheless, the correlations showed highly significant tendencies toward similarities between the sexes.

Correlations between the increments in pairs of cranial base and mandibular dimensions at FPS were mostly nonsignificant.

Simultaneous Spurts

The synchrony of FPS in the cranial base and in the mandible was judged from the data for 33 boys and 31 girls. One boy and two girls who did not demonstrate recordable spurts in the cranial base were not included in this analysis.

The timing of FPS in cranial base and mandible was measured from the time of the first spurt in each area. FPS appeared first in the cranial base in 22 children, first in the mandible in 19, and in both cranial base and mandible during the same annual age interval in 22.

For the 41 children in whom there was a difference in the timing of cranial base and mandibular spurts, the difference was one year in 23, two years in 16, three years in 1, and four years in 1.

Data for a girl in whom spurts occurred in all six cranial base and mandibular lengths during the year before menarche are shown in Fig. 5. This girl also demonstrated earlier spurts in Ba–N, S–N, Ba–S and Ar–Go, all within the same year. Her increments of growth in the mandible were larger than those in the cranial base. Ar–Gn was initially shorter than Ba–N, but it was longer after 9.5 years. Go–Gn was also considerably shorter than S– N initially, but they were almost equal in length after 13 years. Ar-Go was longer than Ba–S at all ages, and the difference increased with age.

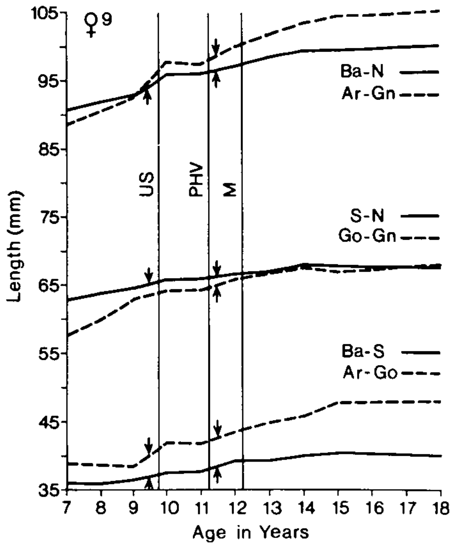

Fig. 5

Serial cranial base and mandibular lengths (mm) in a girl in whom there were synchronous spurts in all six dimensions; additional early spurts are seen in four of the lengths.

US = Age at onset of ossification in the ulnar sesamoid

PHV = Age at peak height velocity

M = Age at menarche

— Discussion —

In the present sample, pubertal spurts exceeding the minimum criteria used in this study were common in both the cranial base and in the mandible. In the mandible they were more prevalent in boys than in girls, but frequency of cranial base spurts was similar in both sexes.

As reported earlier from analyses of data from many of the same children (Lewis and Roche 1972 1974, Lewis et al. 1982), FPS in the cranial base tended to occur about 1.6yr earlier in girls than in boys, with similar differences in the timing of mandibular spurts. These differences are in agreement with other reports (Nanda 1955 1956, Bambha 1961).

The increments at FPS tended to be larger in boys than in girls for all dimensions, similar to reports by Baughan et al. (1979), by Nanda (1955) for sex differences in percentage increase in length from 10yr to 17yr, and by Brown et al. (1971) for peak rates of growth of cranial base and mandible.

In the present study, decelerations were found before FPS in the median values for each dimension. Rates of growth during the year preceding FPS were usually greater in the girls than in the boys, but there was an opposite sex difference in the year after FPS (Table 2).

The occurrence of larger spurts in the mandible than in the cranial base is consistent with reports that the mandible seems to follow a general pattern of growth similar to that of stature, whereas the growth of the cranial base is intermediate between the neural and general patterns (Baughan et al. 1979, Ludwick 1958). These different patterns lead to changes in ratios between lengths of the cranial base and the mandible with age (Dolan 1967, Sakamoto et al. 1963).

The timing of FPS in cranial base and mandible was only slightly related to PHV (Lewis and Roche 1972 1974, Lewis et al. 1982). The commencement of FPS tended to precede PHV, with Ba–N, Go–Gn and Ar–Gn the earliest (mean difference from PHV about 0.7yr in boys and 0.4yr in girls). The latest in relation to PHV were S–N and Ar–Go (mean difference about 0.3yr in boys and 0.15yr in girls).

Standard deviations show wide variation in the intervals by which FPS preceded PHV, averaging about 1.1yr in both sexes. The first spurt occurred as late as three years after PHV in some individuals.

Median FPS occurred about 1.5yr before menarche, with a 1.2yr standard deviation. The mean interval was longest for Go–Gn and Ba–N (1.7yr) and shortest for Ar–Go and S–N (1.1yr).

Decelerations occurred in all dimensions prior to the maximum median increments calculated in relation to menarche. These decelerations were usually slightly earlier in the cranial base than in the mandible. The maximum values for the median increments ranged from two years before menarche to the time of menarche, tending to be slightly earlier in the cranial base (Lewis and Roche 1972, Lewis et al. 1982).

The timing of FPS was also related to US, which usually preceded spurts for all six lengths. However, the median rates of elongation of Ba-S changed little in relation to US (Lewis and Roche 1972 1974, Lewis et al. 1982).

The variability of the timing of FPS in the six dimensions in relation to chronological age, PHV, US and menarche has been evaluated previously using the standard deviations of the means for age at FPS. These comparisons show FPS in cranial base and mandible more closely correlated to PHV than to the onset of ossification of the ulnar sesamoid or age at menarche (Lewis and Roche 1972 1974, Lewis et al. 1982).

This is in agreement with the low correlations reported between ages at US and at maximum rate of craniofacial growth found by Pileski et al. (1973) and Brown et al. (1971), and the loose associations between the timing of US and PHV reported by Onat and Numan-Cebeci (1976) and Hägg and Taranger (1980, 1982). In the present data, the timing of FPS in cranial base and mandible was also found to be not closely related to US. Maximum rates of craniofacial growth generally tended to occur after US.

Orthodontic implications

Interest in the possible use of US as a substitute for the complete assessment of hand-wrist skeletal age (as with the Greulich-Pyle Atlas, 1959) has been expressed in the orthodontic literature. This interest is based on the proposition that the timing and hence the effectiveness of treatment can be affected by rates of growth and levels of circulating hormones which are related, in turn, to levels of maturity (Burstone 1963, Björk 1972).

There is a widespread belief that skeletal age is related to craniofacial growth and possibly to spurts in the growth rate. While many studies have been based on very small samples, they do support views that skeletal age is associated with such factors as the timing of maximum growth rates in the craniofacial area (Brown et al. 1971, Bergersen 1972), craniofacial growth increments and percentage of the adult length of S-N that has been achieved (Johnston et al. 1965), and with craniofacial size (Moss et al. 1956, Hughes 1958, Seide 1959, Greene 1964, Moreschi 1964, and Johnston et al. 1965).

It has also been reported that the timing and magnitude of maximum craniofacial growth rates are more closely related to chronological age than to skeletal age (Luks 1969, Thompson et al. 1976). Hunter's findings (1966) are in agreement with that concept for girls but not for boys. Rose (1960) has noted that craniofacial size is not closely related to skeletal age, and Bambha and Van Natta (1963) report that such a relationship occurs among extreme maturity groups only.

In early analyses of data from the present study sample, only small differences were noted in the timing of craniofacial growth spurts in relation to chronological or skeletal age (Lewis and Roche 1972 1974, Lewis et al. 1982).

Despite the differences in the literature, there is an underlying assurance that skeletal age can be effectively applied in orthodontic practice. Attempts to use US as an indicator of skeletal age continue. Pavia and Sempé however, show that this indicator may not be useful if used alone. The critical limitation is that it tends to occur too close to the maximum rate of growth to be useful in prediction (Brown et al. 1971).

The amount of information concerning maturity available from any one indicator is limited (Roche et al. 1975). The variations seen in the sequence of indicators seriously limit the usefulness of single indicators such as US or ossification of the hook of the hamate (Garn and Rohmann 1960, Garn et al. 1966, Brown et al. 1971).

The skeletal maturation rates of individuals can change in unpredictable ways (Hunter 1966), even though the correlations for groups may be high across intervals as long as 4 years (Roche et al. 1974).

Little attention has been given to associations between stature and craniofacial growth within individuals. Nanda (1955 1956), Bambha (1961) and Hunter (1966) relate the timing of craniofacial growth spurts to the timing of spurts in stature.

Comparison of small groups of tall and short boys in the present sample showed no difference in mean FPS, and the short and tall boys did not differ in mean age at PHV, yet the total increment from PHV to age 18 was larger in the short boys.

The timing of FPS between pairs of cranial base and mandibular lengths was significantly correlated, with higher correlations for girls than boys. There was no correlation between overall length and length of increment. The present sample was almost equally divided between those in whom FPS occurred earlier in the cranial base, earlier in the mandible, or simultaneously in both areas. This variability in sequence is consistent with the marked variability found throughout the skeleton in the sequence with which bones exhibit their maximum rates of pubescent growth (Roche 1974).

The literature comparing the sequence of spurts between the cranial base and the mandible is sparse. Nanda (1955, 1956), studying a small group, concluded that the spurts in growth are nearly synchronous between the two areas. Bambha (1961) and Dolan (1967) present evidence that the maximum rates of growth for the two areas tend to be synchronous, although Dolan considered that there was a slight tendency for the mandibular FPS to occur later. Baughan et al. (1979) concluded that FPS tended to occur earlier in the mandible than in the cranial base.

Differences have been reported between the patterns of pubertal growth in the cranial base and mandible in girls maturing early or late (Lewis and Roche 1972, Lewis et al. 1982). These girls differed in age at menarche, PHV and US. Intervals between pubertal events tended to be shorter in early- maturing girls, who also tended to exhibit slightly larger spurts. The early-maturing girls appeared smaller than the late-maturing girls in all six dimensions before FPS,and differences between the two groups remained small until FPS in the late-maturing girls, when their measurements became larger.

Comparisons have been reported between children of each sex who pass rapidly through pubescence and those in whom the intervals between pubertal events are long (Lewis and Roche 1972 1974, Lewis et al. 1982). The pubertal events evaluated were US and PHV, plus menarche for the giris. There was no consistent tendency for the size of FPS or the increment at FPS in cranial base or mandibular measurements to differ between children who passed rapidly through puberty and those in whom these changes occurred more slowly.

— Summary —

Serial data from cephalometric radiographs were analyzed for 34 boys and 33 girls who had cephalometric radiographs annually near each birthday from at least age 7 through 18 years. Spurts were defined for this study as increases between successive cranial base increments that exceeded 0.75mm/year in boys

or 0.5mm/year in girls. The corresponding criterion for the mandible was 1.0mm/year in either sex. Pubescence was defined as the 4- year period spanning 2 years before and after peak height velocity.

Spurts during pubescence were common, tending to occur about 1.6yr earlier in girls than boys. The mean increments at first pubertal spurt (FPS) and the mean sizes of FPS were about 25% to 33% greater in the boys than in the girls. The rate of growth during the year before FPS tended to be greater in the girls, while in the year after FPS it tended to be greater in the boys.

The timing of FPS in either cranial base or mandible was not closely related to the onset of ossification in the ulnar sesamoid, the age at peak height velocity, or age at menarche. FPS generally occurred after the onset of ossification of the ulnar sesamoid, but before peak height velocity and menarche.

There was no evidence of difference between craniofacial FPS in children who passed rapidly or slowly through pubescence, nor was any difference noted between the size of pubertal spurts in tall or short boys. Larger total increments after peak height velocity were found in the short boys.

Significant correlations were indentified between the cranial base and the mandible in the *timing* but not in the magnitude of FPS. The children were approximately equally divided between those in whom cranial base spurts occurred first, those in whom mandibular spurts were first, and those in whom FPS occurred in both areas within the same annual interval.

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