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Analysis of the growth spurt at age seven (mid-growth spurt)[1, 2]

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Summary

A statistical analysis of the mid-growth spurt from the data of the First Zurich Longitudinal Study is presented. A small but significant mid-growth spurt was found in most height and length measurements and in some girth and width measurements, such as chest circumference, bihumeral and biiliac width. The mid-growth spurt seemed to be slightly more pronounced in boys than in girls. The peak of the mid-growth spurt occurred between 6.5 and 8.5 years. The height of the peak varied from 0.3 to 0.7 cm/year for the different measurements (estimated from the smoothed median velocity curves). In a peak-centered analysis a mid-growth spurt of standing height was observed in two thirds of the children. It occurred about one year earlier in girls than in boys, and averaged 1.4 cm/year. The data indicate that the mid-growth spurt is due to a transient increased growth rate of the bones, particularly the long bones, and possibly of fat and muscle tissue. In contrast to the growth spurt of the extremities, the spurt of the rump height is not a true growth phenomenon, but the result of a postural change occurring at about 6.5 years of age.

Zusammenfassung

Im Rahmen der Ersten Zürcher Longitudinalstudie wurde eine statistische Auswertung des sogenannten präpubertären Wachstumsschubes (Erste Streckung) vorgenommen. Ein kleiner, aber signifikanter präpubertärer Wachstumsschub konnte für die meisten Längenmasse sowie für einige Umfangs- und Durchmessermasse nachgewiesen werden. Der Wachstumsschub trat bei den Knaben etwas ausgeprägter in Erscheinung als bei den Mädchen. Der prä-

[1] Dedicated to Professor F. Bamatter, Geneva, at the occasion of his 80th birthday
[2] Abbreviations used: APH = age of peak height velocity; PH = peak height

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pubertäre Wachstumsschub wurde zwischen 6,5 und 8,5 Jahren beobachtet. Die Höhe des Wachstumsschubes variierte zwischen 0,3 und 0,7 cm/Jahr für die verschiedenen Körpermasse (geschätzt aus den geglätteten Mediankurven). In einer longitudinalen (peak-centered) Auswertung wurde ein präpubertärer Wachstumsschub der Stehhöhe bei zwei Dritteln der Kinder beobachtet. Er trat bei den Mädchen etwa ein Jahr früher auf als bei den Knaben und war im Mittel 1,4 cm/Jahr hoch. Der präpubertäre Wachstumsschub scheint durch einen vorübergehenden Anstieg der Wachstumsgeschwindigkeit des Skelettes (vor allem der langen Röhrenknochen) und möglicherweise auch des Fett- und Muskelgewebes bedingt zu sein. Während es sich bei dem präpubertären Wachstumsschub der Extremitäten um einen echten Wachstumsvorgang handelt, scheint derjenige des Rumpfes lediglich Ausdruck einer Änderung in der Körperhaltung im Alter von 6 bis 7 Jahren zu sein.

Résumé

Nous présentons une analyse statistique de la poussée de croissance prépubérale (mid-growth spurt) à l'aide des données de la Première Etude Longitudinale de Zurich. Une poussée de croissance mineure mais significative est évidente dans la plupart des mesures de hauteur et longueur, mais aussi dans certains périmètres et diamètres, tels que le périmètre de la poitrine et le diamètre bicrète. Cette poussée de croissance paraît légèrement plus prononcée chez les garçons que chez les filles. Le pic se situe entre 6,5 et 8,5 ans. Sa hauteur, estimée à partir d'une courbe moyenne convexe et lissée, varie pour les différents paramètres entre 0,3 et 0,7 cm/an. Par une analyse de la stature debout où les courbes de croissance individuelle sont centrées par rapport à ce pic, on trouve cette poussée de croissance dans deux tiers des enfants. On l'observe à peu près un an plus tôt chez les filles que chez les garçons et on estime sa hauteur à 1,4 cm/an. Les données suggèrent que cette poussée est due à une accélération temporaire de la croissance des os et, probablement, aussi de la masse musculaire et du tissu adipeux. Cela s'applique surtout à la poussée de croissance des extrémités, tandis que la poussée du tronc n'est pas un phénomène authentique de croissance, mais plutôt le résultat d'un changement de posture, qui se situe environ à l'âge de 6,5 ans.

In studies on physical growth, two periods of increased growth rates are observed from birth to adulthood: The so-called mid-growth spurt occurs at age 6 to 8, the adolescent growth spurt at age 10 to 16. Whereas the latter received much attention in the past [8, 9, 18], the former was reported only sporadically. Some older growth studies indicated a mid-growth spurt in height [2, 3, 7, 10]. TANNER [17] postulated a mid-growth spurt for breadth but not for length measurements. In some recent papers, individual height velocity curves are

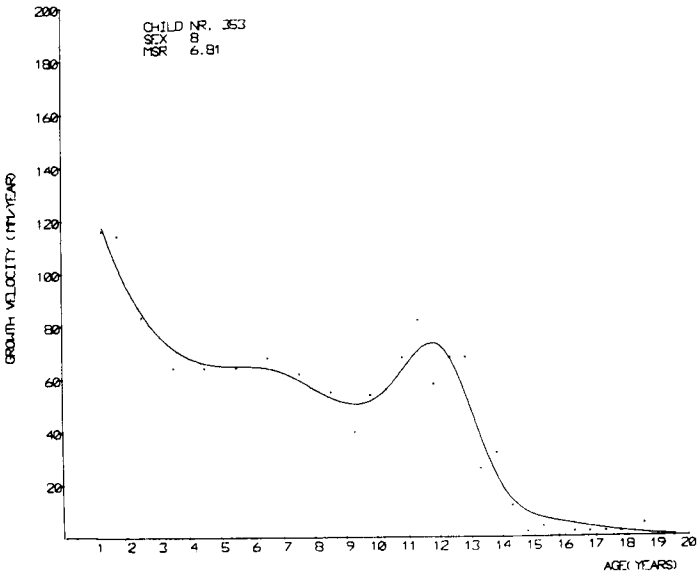


Fig. 1. Individual height velocity curve showing a midgrowth spurt at age 6.5.

published which show a mid-growth spurt [4, 6, 13]. Fig. 1 gives an example of such an individual height velocity curve showing a mid-growth spurt at age 7 (the curve was obtained by using shape invariant modeling [16]). Since the mid-growth spurt has never been investigated in a systematic way, a statistical analysis of this growth phenomenon was carried out. The results of this analysis are presented in this article.

Subjects and methods

Subjects

This study was based on the data of the First Zurich Longitudinal Study of Growth and Development 1954–1979 [12]. Data from 3 to 11 years of age were used for computations. In this age range, the number of subjects varied from 130 to 150 in each sex.

Measurements and editing

The measurements were performed according to the direction of the Centre International de l'Enfance in Paris (CIE) [5]. Before the age of 9 years in girls and 10 years in boys the children were measured yearly at birthday ± 14 days. Thereafter, they were measured 6-monthly within the same time limits. The measurements were done by two trained anthropometrists. Editing was done as outlined in LARGO et al. and PRADER et al. [8, 12].

Methods

In order to check the statistical significance of a peak observed in the age range 5 to 9 years, we proceeded as follows: For every child we computed:

$$D_r = V_r - \frac{V_{r+2} + V_{r-2}}{2}$$

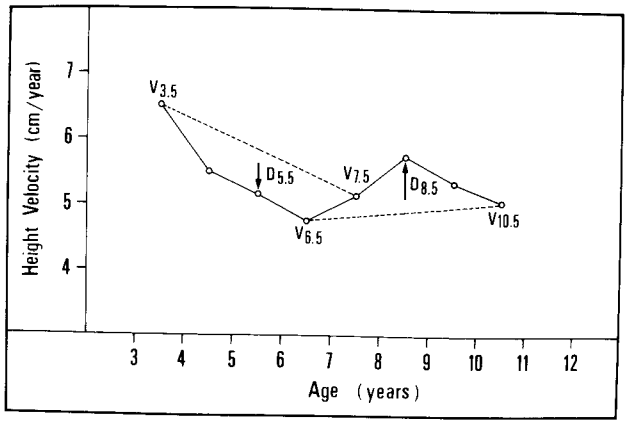


Fig. 2. Computations of D_r's (see methods).

V_r denotes the growth velocity (yearly increments in distance) of any measurement taken at age r years (Fig. 2). Under the null hypothesis of a convex growth velocity curve between birth and puberty, we would expect D_r to be negative, if not for measurement errors. This hypothesis of convexity in the age range of 3.5 to 10.5 years was tested by computing the mean and standard deviation of D_r over the sample for each sex separately and by defining

$$d_r = \frac{\bar{D}_r}{SD(\bar{D}_r)} \qquad (r = 5.5, 6.5, 7.5 \text{ and } 8.5 \text{ years})$$

In addition a standardized Wilcoxon test (W_r) of the null hypothesis $D_r \leq 0$ was computed. The largest d_r was than taken as test value, positive value speaking for the rejection of the null hypothesis. The significance of the largest d_r's was checked against the corresponding value of max (z_1, z_2, z_3, z_4) with z_i standard normal. The d_r's (and the W_r's) can be considered as standard normal, but not independent over age. Although the dependence structure is not known, the significance of the test was underestimated by the use of Bonferroni's inequality:

$$P(\max(z_1, z_2, z_3, z_4) \geq c \leq 4\,P(z \geq c)$$

The critical values of c are as follows:

P	0.1	0.05	0.01	0.001
c	1.96	2.24	2.81	3.48

Results

Significance of the mid-growth spurt

Table 1 contains the largest d_r's together with the corresponding age r, the number of children, D_r and W_r. A significant mid-growth spurt was found in a number of growth measurements. It was particularly seen in height and length measurements such as standing, sitting and leg height, supine and leg length. No mid-growth spurt could be found in crown-rump length. A mid-growth spurt was further observed in girth measurements such as chest circumference and width measurements, particularly bihumeral and biiliac width. The mid-growth spurt seemed to be slightly more pronounced in boys than in girls.

Table 1. Significance of the mid-growth spurt

Growth parameters	Boys					Girls				
	Age	N	$\bar{D}_r$	d_r	W_r	Age	N	$\bar{D}_r$	d_r	W_r
Weight	6.5	105	0.08	0.76	0.75	6.5	105	0.17	1.60	1.71
Supine length	7.5	108	0.54	6.14***	5.48	7.5	101	0.12	1.36	2.08
Crown-rump length	7.5	104	0.12	1.55	1.15	6.5	65	0.04	0.33	0.20
Supine subischial leg length	7.5	104	0.42	4.23***	3.76	8.5	97	0.35	3.47***	3.46
Standing height	7.5	112	0.50	6.68***	5.89	7.5	108	0.29	3.29**	3.50
Sitting height	6.5	103	0.77	6.15***	5.39	6.5	103	0.37	2.66*	2.67
Standing subischial leg height	8.5	118	0.35	3.64***	3.40	8.5	100	0.27	2.10	2.00
Chest circumference	6.5	106	0.82	3.96***	3.86	6.5	104	0.91	4.43***	3.98
Head circumference	6.5	106	0.01	0.24	0.12	6.5	104	0.07	1.89	1.77
Upper arm circumference	7.5	111	0.18	2.58*	2.26	6.5	105	0.13	1.57	1.26
Calf circumference	6.5	107	0.10	1.48	1.68	6.5	104	0.21	2.46*	2.63
Femur bicondylar width	6.5	107	0.01	0.32	0.07	6.5	104	0.05	2.40*	3.20
Humerus bicondylar width	8.5	115	0.01	0.65	0.50	all d_r negative				
Biiliac width	7.5	72	0.15	2.92**	3.58	7.5	69	0.11	2.20	2.89
Bihumeral width	6.5	65	0.72	5.26***	4.50	6.5	64	0.74	5.87***	4.79
Head biparietal diameter	7.5	111	0.02	1.41	0.73	7.5	106	0.01	0.55	0.54
Head fronto-occipital diameter	all d_r negative					all d_r negative				
Arm length	8.5	115	0.06	6.55***	5.56	5.5	100	0.02	1.01	0.08

* $p < 0.05$ ($d_r > 2.24$) ** $p < 0.01$ ($d_r > 2.81$) *** $p < 0.001$ ($d_r > 3.46$)

Age = age of the largest d_r; N = number of children; $\bar{D}_r$ = measure for the height of the midgrowth spurt (in cm/year for all measurements except weight [kg/year]); d_r = measure for the significance of the midgrowth spurt; W_r = Wilcoxon test. For more detailed explanations see methods.

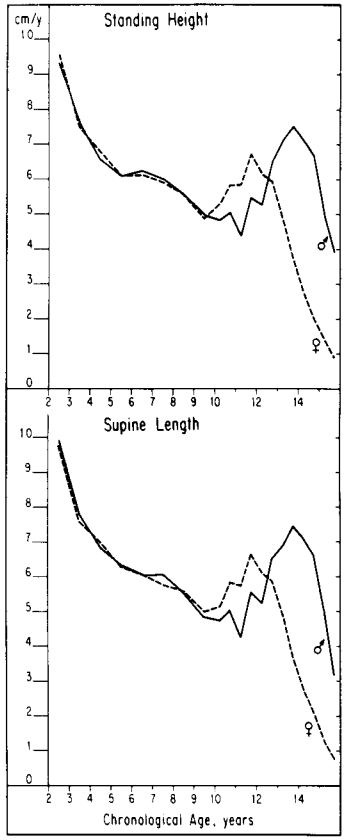


Fig. 3

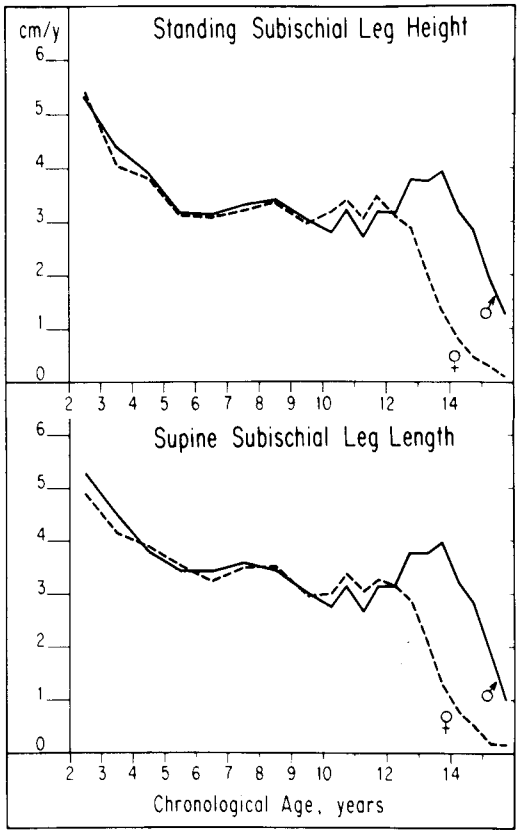
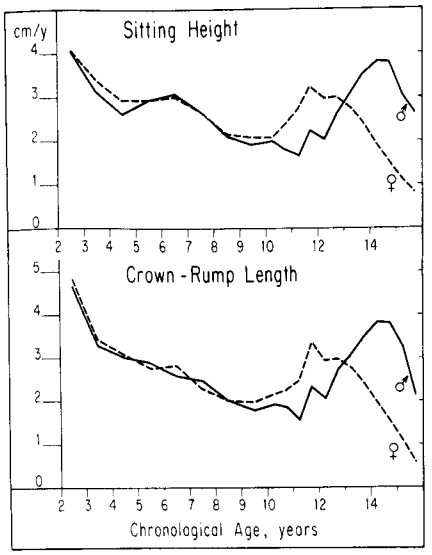


Fig. 4

Fig. 3. Raw mean velocity curve of standing height and of supine length.

Fig. 4. Raw mean velocity curve of standing subischial leg height and of supine subischial leg length.

On the raw mean velocity curves a well defined peak (to be understood as a deviation from convexity) was observed, consistent in both sexes, for all heights, leg length, chest circumference and bihumeral width, a less clear one for biiliac width and supine length and no peak for crown-rump length (Figs. 3–7). The mid-growth spurt and the adolescent growth spurt as well extended over a period of serveral years. In contrast to these two growth spurts, variations of the mean growth velocity curve, mainly due to measurement errors, covered only annual periods. They were particularly well seen when the measurements were carried out six-monthly (after the age of 9 years in girls and of 10 years in boys).



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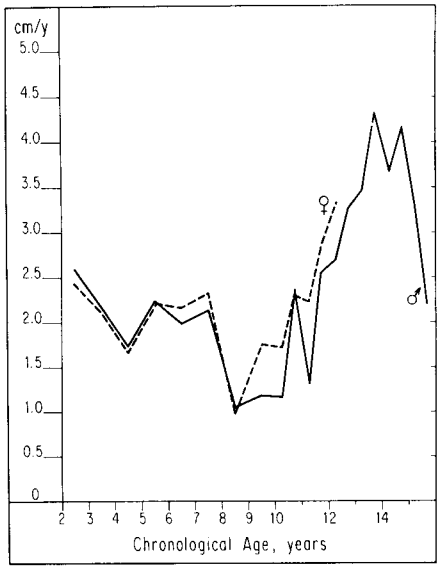

Fig. 6

Fig. 5. Raw mean velocity curve of sitting height and of crown-rump length.

Fig. 6. Raw mean velocity curve of chest circumference.

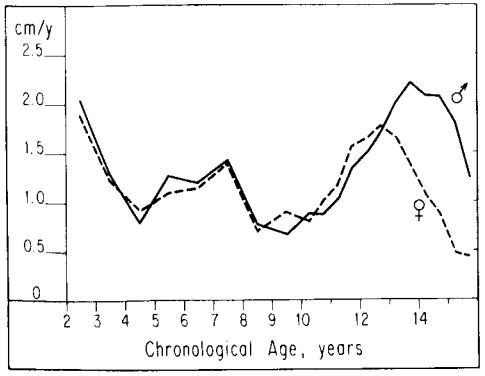

Fig. 7

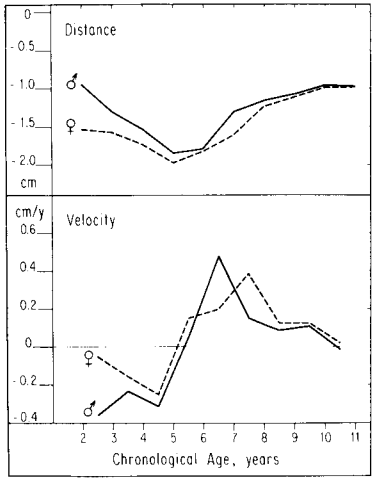

Fig. 8

Fig. 7. Raw mean velocity curve of bihumeral width.

Fig. 8. Sitting height minus crown-rump length.

Table 2. Timing and peak height of the mid-growth spurt (obtained from the smoothed median curves)

		APH (years)	PH (cm/year)	SE* (cm/year)
Standing height	m	7.25–7.75	0.7	0.07
	f	7.25–7.75	0.5	
Supine length	m	7.75–8.25	0.6	0.08
	f	7.75–8.25	0.4	
Sitting height	m	6.50–7.00	0.7	0.09
	f	6.50–7.00	0.6	
Crown-rump length	m	–	–	0.07
	f	–	–	
Standing-subischial-leg height	m	8.00–8.50	0.7	0.1
	f	8.00–8.50	0.3	
Supine-subischial-leg length	m	8.00–8.50	0.5	0.08
	f	8.00–8.50	0.5	
Chest circumference	m	6.50–7.00	0.7	0.15
	f	6.75–7.25	0.7	
Bihumeral width	m	7.00–7.50	0.5	0.1
	f	7.00–7.50	0.5	

* an approximate average standard error of the mean velocity curve in the age range condidered

Table 3. Age of peak height and peak height of the midgrowth spurt in standing height (obtained from peak-centered individual velocity curves)

	APH (years)	PH (cm/year)	% of children with observable peak
Boys	7.5–8	1.4 cm	50–70
Girls	6.5–7	1.4 cm	50–70

Timing and height of the mid-growth spurt

For those measurements which showed a significant mid-growth spurt, age at peak height velocity (APH) and peak height (PH) were derived graphically from the smoothed median velocity curves [12] postulating an underlaying convex velocity curve (Tab. 2). APH was found at the age of 6.5 to 8.5 years. APH of sitting height seemed to occur relatively early, that of leg height and leg length relatively late. PH was found to be between 0.3 and 0.7 cm/year.

It has to be assumed that the mid-growth spurt does not occur in all children at the same chronological age. Thus, the estimation of standard parameters such as mean age at peak height and mean peak height velocity requires the centering of the individual growth velocity curves, as it was carried out in recent studies on the adolescent growth spurt [8, 18]. This centering procedure was tentatively performed for standing height using individual velocity curves generated by a shape invariant model [16]. A mid-growth spurt was observed in about two thirds of the children (Tab. 3). It seemed to occur approximately one year earlier in girls, namely between 6.5 and 7 years, than in boys and averaged 1.4 cm/year in both sexes. As expected PH calculated from the peak-centered curves was considerably higher than PH calculated from the smoothed median curves. However, this result should be taken with caution, because the shape invariant model could not easily differentiate between children with and without peak. In addition, the individual peak was often in the order of the magnitude of the measurement error. For these two reasons, we did not pursue a more detailed analysis of all measurements by centering the individual growth velocity curves.

Discussion

A significant mid-growth spurt («Erste Streckung») was demonstrated for a number of measurements. Height and length measurements such as leg height point towards a mid-growth spurt of the bones. Girth and width measurements such as chest circumference and bihumeral width may indicate also a mid-growth spurt of fat and/or muscle tissue. This is also suggested by the mid-growth spurt in upper arm circumference and calf circumference which, however, is not highly significant and not consistent in both sexes. A mid-growth spurt of fat tissue could not be further clarified because of the large variation of skin-fold measurements at all prepubertal ages.

As far as the rump is concerned, there was a puzzling discrepancy between length and height measurements. Whereas crown-rump length showed no significant mid-growth spurt, a clear-cut mid-growth spurt of sitting height was observed (Fig. 5). This spurt seemed to be due to postural changes indicating a diminution of the kypholordotic curvature of the spine between 5 and 7 years in the sitting position. This view is supported by the fact that the difference between sitting height and crown-rump length did not remain constant over age (Fig. 8). The difference of sitting height minus crown-rump length changed considerably between 4.5 and 6.5 years indicating a postural change in the sitting child. A similar, but less pronounced effect could be observed for the difference between standing height and supine length. Whether this postural change is due to a pelvic tilt occurring at this age [1], or to other factors requires further investigation.

It should be emphasized that the mid-growth spurt was not seen in all children and that in those with a spurt, the peak was fairly small, just beyond the range of the measurement error. The moderate incidence and its small magnitude explain why it is mentioned in the literature occasionally only, and has never been studied in detail. Our analysis, however, shows that the mid-growth spurt is a small but real growth phenomenon.

It is tempting to speculate about the cause of the mid-growth spurt. Since the plasma concentrations of the main adrenal androgen dehydroepiandrosterone and its sulfate start to increase in both sexes between the age of 5 and 8 [11, 14, 15] and since androgens stimulate growth, the spurt may be related to an increased production of adrenal androgens (adrenarche), whereas the pubertal growth spurt in boys is related to the increased production of gonadal androgens (gonadarche). However, this hypothesis makes the transient nature of the mid-growth spurt difficult to understand.

1 Asher C.: Postural variations in childhood Butterworths, London 1975.
2 Backman G.: Das Wachstum der Körperlänge des Menschen. Kunglicke Svenska Vetenskapsakademiens Handlingar *14*, 145 (1934).
3 Count E.W.: Growth patterns of the human physique: an approach of kinetic anthropometry. Hum. Biol. *15*, 1 (1943).
4 El Lozy M.: A critical analysis of the double and triple logistic growth curves. Ann. hum. Biol. *5*, 389 (1978).
5 Falkner F.: Child development. An international method of study. Mod. Probl. Pediat. *5* (1960).
6 Falkner F.: The physical development of children. Pediatrics *29*, 448 (1962).
7 Grubb R.: Das Wachstum der Körperlänge beim weiblichen Geschlecht. Acta paediat. scand. *30*, 67 (1942).
8 Largo R.H., Gasser T.H., Prader A., Stuetzle W., Huber P.J.: Analysis of the adolescent growth spurt using smoothing spline functions. Ann. hum. Biol. *5*, 421 (1978).
9 Marubini E., Resele L.F., Tanner L.M., Whitehouse R.H.: The fit of Gompertz and logistic curves to longitudinal data during adolescence on height, sitting height and biacrominal diameter in boys and girls of the Harpenden Growth Study. Hum. Biol. *44*, 511 (1972).
10 Meredith H.V.: The rhythm of physical growth: a study of 18 anthropometric measurements on Iowa City white males ranging in age between birth and 18 years. Univ. Iowa Stud. Child. Welf. *11*, 128 (1935).
11 Peretti E., Forest M.G.: Pattern of plasma dehydroepiandrosterone sulfate levels in humans from birth to adulthood. J. clin. Endocr. Metab. *47*, 572 (1978).
12 Prader A., Issler C., Molinari L., Largo R.H.: Physical growth in Swiss children from birth to 20 years of age. Will be published in Helv. paediat. Acta.
13 Preece M.A.: Analysis of the human growth curve. Postgrad. med. J. *54* (suppl. 1), 77 (1978).
14 Roger M., Nahoul K., Toublanc J.E., Castanier M., Canlorbe P., Job J.G.: Les androgènes plasmatiques chez le garçon de la naissance à l'adolescence. Ann. Pédiat. *26*, 239 (1979).
15 Sizonenko P.C., Paunier L.: Hormonal changes in puberty. III. Correlation of plasma dehydroepiandrosterone, testosterone, FSH, and LH with stages of puberty and bone age in normal boys and girls and in patients with Addison's disease or hypogonadism or with premature or late adrenarche. J. clin. Endocr. Metab. *41*, 894 (1975).
16 Stützle W., Gasser T., Molinari L., Largo R.H., Prader A., Huber P.J.: Shape-invariant modeling of human growth. Will be published in Ann. hum. Biol.
17 Tanner J.M.: The morphological level of personality. Proc. roy. Soc. Med. *60*, 17 (1947).
18 Tanner J.M., Whitehouse R.H., Marubini E., Resele L.: The adolescent growth spurt of boys and girls of the Harpenden Study. Ann. hum. Biol. *3*, 109 (1976).