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THE GROWTH PATTERNS IN THE UPPER EXTREMITIES OF PRAGUE SCHOOL AGE CHILDREN

INTRODUCTION

Growth and development of the human being represents a topic of continuous interest to medical and biological sciences as the basic laws controlling this complex process are not fully understood yet. Data for objective evaluation of this process are mainly supplied through anthropological studies which follow both the growth of human body as complex and of its various individual parts. These studies may then be used to give a general picture of the nature of growth and of its acceleration, slowing or completion.

Important aspect of this research represents the influence on organism of such factors like increased life comfort (e.g. nutrition, hygiene), improved medical care etc. These improvements seem to be the main reason for longlasting acceleration in growth and development of the human being. Results obtained from these studies are then used in clinical praxis as pediatric standards for particular age and sex. These standards for healthy children of given age can be obtained efficiently using cross — sectional data only (Tanner 1962).

Requirements of individual clinical specialists frequently result in further detailed anthropological studies of growth and development of individual parts of the human body as of head (for the needs of clinical neurology), face (plastic surgery, orthodonties), upper and lower extremities (plastic surgery, orthopedy) and so on.

Part of the body which received a relatively little attention in the past seems to be the upper limb. There are relatively few studies which cover the growth and development of the upper limb as a complex of its individual segments. In Czech literature Borovanský and Hněvkovský (1930) seems to be the first who described the development of

segments of the upper extremities within the group of Prague boys. After the World War II Lisoněk and Hrnčíř (1960) analysed the relationship between the length of both extremities and height of the body in boys from Moravia. The growth of individual segments and their participation in the length of the upper limb has been studied by Zrzavý (1964) and the length of humerus, forearm and hand within Prague children by Říčař (1954). Pařízková's longitudinal study (1972) of Prague boys with different degree of physical activity includes some measures of the upper extremities too. Growth of the upper limb of preschool children was analysed by Zrzavý et al. (1966).

A little greater amount of data seems to be available concerning the length and breadth measures of hand of our and European children (Jelínek 1950, Pospíšil 1959, Drobný 1959, Hajniš 1969, Hajniš 1970). In these and other studies (Voločkoj 1924, Koenner 1938, Titlbachová 1949, Rössler 1958, Gavrilovič 1969, Štofková and Valšík 1972) the relative length of fingers has been analysed in addition.

Child growth and development is a topic of interest of many other studies and in part of them the basic measures of the upper limb are included (Baldwin 1924, Wallis 1931, Meredith 1935, Boynton 1936, Yanev et al. 1965, Singh 1970, Rajkai 1970).

Hand physique and mutual ratio of individual segments of the upper extremities in samples of students and adults from ergonomic point of view has been analysed in recent years for example by Garrett (1971), Lewin and Skrobak-Kaczynski (1972). Another studies deal either with the influence of work on the hand physique and form or with the differences in hand morphology

TABLE 1

Total upper limb length (cm)

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	51.65	3.06	51.69	3.02	24	52.35	2.44	52.25	2.45
7 - 8	57	54.44	2.73	54.37	2.74	34	53.46	2.78	53.43	2.78
8 - 9	36	56.99	3.04	56.99	3.01	38	55.69	3.04	55.61	3.01
9 - 10	28	60.15	2.92	60.13	2.89	27	58.53	3.48	58.49	3.47
10 - 11	26	61.95	2.78	62.01	2.76	30	60.20	3.04	60.19	3.03
11 - 11.5	31	63.33	3.03	63.33	2.96	32	64.53	3.23	64.43	3.21
11.5 - 12	30	65.27	4.00	65.16	4.00	33	65.77	3.38	65.71	3.39
12 - 12.5	32	67.37	3.36	67.24	3.30	34	65.47	2.82	65.33	2.83
12.5 - 13	32	67.37	3.36	67.24	3.30	34	68.63	2.63	68.55	2.64
13 - 13.5	33	69.19	3.39	69.10	3.36	33	69.22	2.83	69.12	2.84
13.5 - 14	33	71.39	3.71	71.36	3.70	33	68.98	3.37	68.88	3.37
14 - 14.5	35	74.18	4.03	74.08	3.95	33	70.46	2.77	70.36	2.79
14.5 - 15	33	74.02	2.95	73.94	3.03	35	70.45	2.92	70.33	2.91
15 - 15.5	32	75.83	3.32	75.71	3.32	33	70.21	2.84	70.18	2.88
15.5 - 16	32	76.87	3.89	76.77	3.93	31	70.93	2.36	70.78	2.38
16 - 17	30	77.00	3.21	76.88	3.21	32	71.59	2.93	71.43	2.99
17 - 18	32	78.19	3.59	78.03	3.57	34	71.19	2.50	71.02	2.54

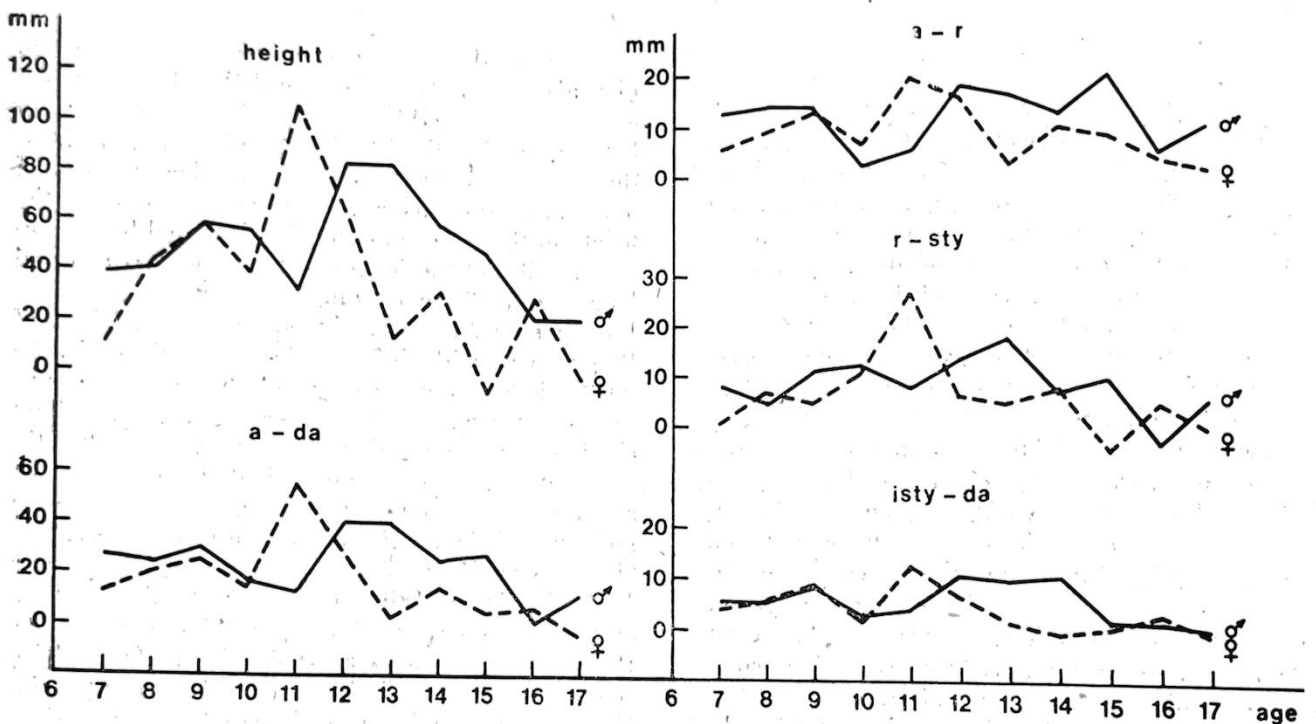


FIG. 1. Velocity curves for height, total arm length and the lengths of its segments.

between different working professions (Jarcho 1926, Roubal and Pachner 1941, Chochol 1949, Roubal 1961, Herig 1964, Tihelková 1966, Matzdorff 1968, Škvařilová 1969). Growth and development of the upper limb, its segments and hand in particular has been further studied using rentgenograms (Borovanský and Hněvkovský 1930, Mares 1955, Garrett 1971) and different measuring techniques has been proposed.

This short review shows that the analysis of the growth and development of the upper limb in these studies has been performed for some special purpose and has not been the primary task of these investigations. For thorough assessment of this complex process it is necessary to take into account other important measures of the body as well. This can show to what extent the changes in individual parts of the human body are due to the general trend of acceleration or to some other specific

TABLE 2

Upper arm length (cm)

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	21.69	1.59	21.64	1.61	24	22.22	1.34	22.10	1.34
7 - 8	57	22.97	1.43	22.94	1.44	34	22.76	1.37	22.78	1.45
8 - 9	36	24.34	1.36	24.40	1.42	38	23.63	1.36	23.57	1.31
9 - 10	28	25.68	1.32	25.65	1.30	27	24.84	1.53	24.83	1.53
10 - 11	26	25.82	1.64	25.83	1.61	30	25.38	1.36	25.31	1.31
11 - 11.5	31	26.22	1.26	26.18	1.19	32	26.87	1.46	26.82	1.42
11.5 - 12	30	27.11	1.70	27.05	1.69	33	27.20	1.41	27.13	1.44
12 - 12.5	32	27.87	1.64	27.78	1.64	34	26.90	1.35	26.84	1.33
12.5 - 13	33	28.54	1.56	28.47	1.57	33	28.59	1.44	28.55	1.42
13 - 13.5	33	29.29	1.74	29.18	1.74	33	28.87	1.36	28.79	1.33
13.5 - 14	33	29.29	1.74	29.18	1.74	33	28.67	1.66	28.61	1.66
14 - 14.5	35	30.42	2.00	30.37	2.00	33	29.22	1.46	29.15	1.42
14.5 - 15	33	30.34	1.49	30.35	1.43	35	29.44	1.21	29.26	1.23
15 - 15.5	32	31.68	1.76	31.59	1.78	33	29.44	1.36	29.32	1.38
15.5 - 16	32	32.13	1.88	32.01	1.90	31	30.02	1.10	29.90	1.15
16 - 17	30	32.37	1.68	32.19	1.68	32	30.17	1.60	30.08	1.65
17 - 18	32	33.18	1.77	32.95	1.74	34	30.08	1.45	29.92	1.43

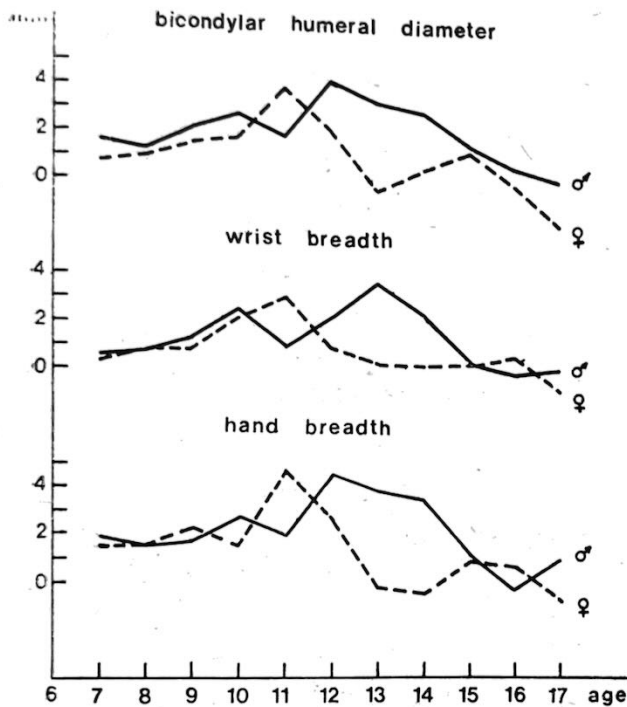


FIG. 2. Velocity curves for breadth measures of the upper limb.

reasons (Fetter et al. 1965, Suchý 1969, Prokopec et al. 1973).

In this study we present the detailed data and analysis of growth and development of the upper limb and of its segments in a sample of Prague school children aged from 6 to 18 years. The main goal of this study is to analyse and compare the growth of individual segments with that of total upper limb and with other measures important for the evaluation of child development.

SAMPLE DESCRIPTION AND METHODS

Investigation of growth and development of the upper extremities included children 6 through 18 years of age from Prague schools. During 1971 to 1972 years cross-sectional data have been collected from 1,140 children 13 of which have later been deleted for different reasons (congenital defects, defects of the upper extremities etc.).

Bearing in mind the demands of clinical praxis children were grouped into chronological age groups, i.e. the six year old age group included children who completed the six but not attained the seven year of age. Hence the mean age of the group was at mid-year, i.e. approximately 6.5 years. Close to the adolescent spurt the children were arranged into half-years groups.

Being sorted in this way each age group comprised approximately 30 individuals. Following anthropometric measures described by Martin and Saller (1957) have been recorded on the child's permanent record: total arm length (a-da), upper arm length (a-r), forearm length (r-sty), hand length (isty-da), bicondylar humeral diameter, wrist breadth, hand breadth, arm circumference, forearm circumference, wrist circumference, hand circumference, height and sitting height. All the measurements were performed simultaneously on both extremities. Relation between either particular measures of the upper limb or in comparison with the other important body dimensions was evaluated using following indexes:

$$\frac{\text{total arm length}}{\text{height}} \times 100$$

$$\frac{\text{total arm length}}{\text{sitting height}} \times 100$$

TABLE 3

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6-7	22	16.48	0.89	16.48	0.86	24	16.78	0.85	16.77	0.87
7-8	57	17.28	0.75	17.24	0.80	34	16.87	0.86	16.87	0.86
8-9	36	17.73	1.04	17.78	1.01	38	17.57	1.04	17.60	1.02
9-10	28	18.77	0.87	18.76	0.88	27	18.02	1.11	18.06	1.10
10-11	26	19.96	0.96	20.02	0.92	30	19.05	1.21	19.15	1.24
11-11.5						32	20.86	1.32	20.83	1.27
11.5-12	31	20.67	1.17	20.68	1.12	33	21.65	1.43	21.65	1.43
12-12.5	30	21.52	1.12	21.51	1.13	34	21.45	1.00	21.39	0.99
12.5-13	32	21.91	1.24	21.89	1.21	34	22.19	0.97	22.18	0.97
13-13.5	33	22.74	1.19	22.69	1.21	33	22.61	1.15	22.59	1.14
13.5-14	33	23.56	1.44	23.60	1.42	33	22.57	1.27	22.48	1.22
14-14.5	35	24.28	1.45	24.27	1.44	33	23.17	1.13	23.20	1.12
14.5-15	33	24.14	1.29	24.08	1.26	33	23.20	1.16	23.23	1.16
15-15.5	32	24.70	1.20	24.63	1.23	35	23.02	1.01	23.00	1.04
15.5-16	32	24.97	1.47	25.05	1.48	33	23.02	0.94	22.72	0.93
16-17	30	24.54	1.09	24.70	1.04	31	23.01	1.14	23.02	1.10
17-18	32	24.97	1.37	25.12	1.36	32	22.87	1.10	22.98	1.10

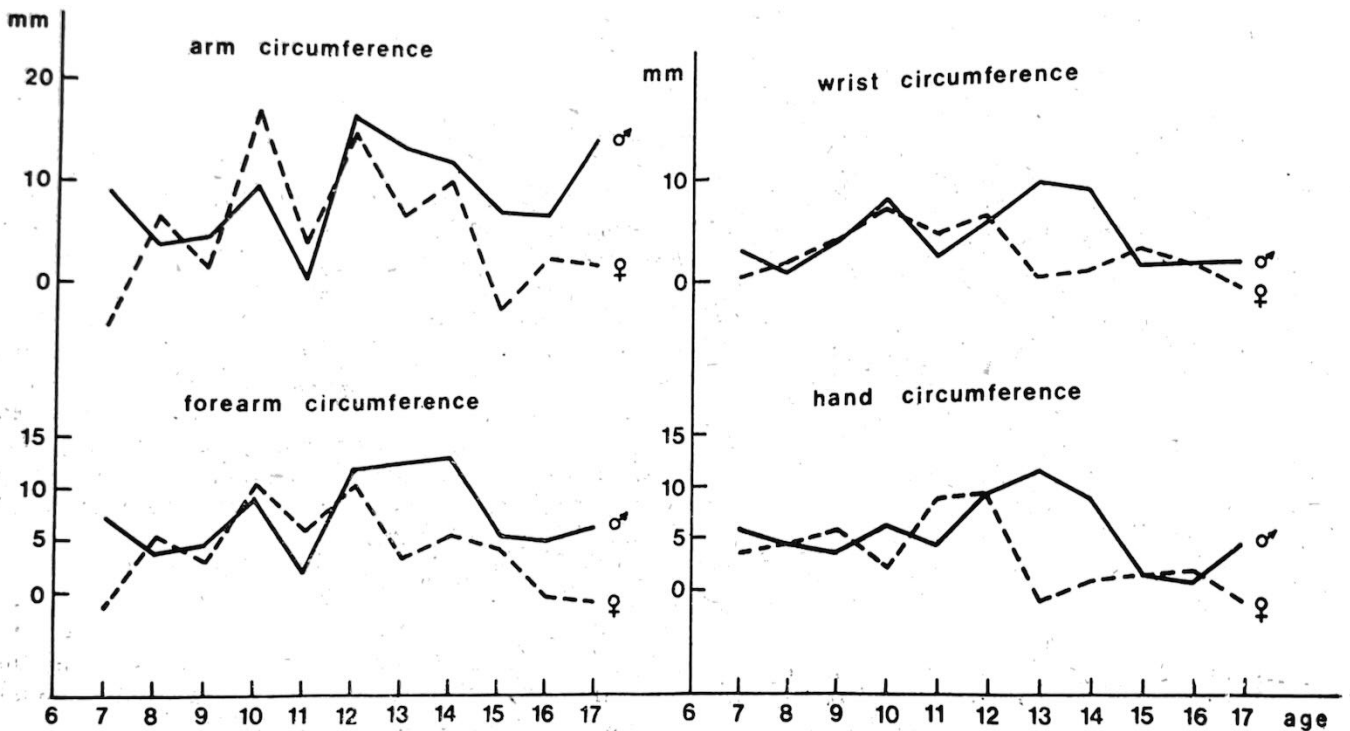


FIG. 3. Velocity curves for circumference measures of the upper limb.

$$\frac{\text{forearm length}}{\text{upper arm length}} \times 100 \quad \text{brachial index}$$

$$\frac{\text{hand breadth}}{\text{hand length}} \times 100$$

Statistical treatment of data included compilation of a mean and standard deviation of a given measure for particular age and sex group. Furthermore annual increments of a mean between sub-

sequent age groups have been calculated either as absolute values or taken relative to the total increment and cumulated with the previous ones, so called cumulative increments.

As these both increments are differences between two subsequent age groups corresponding age given is that of the middle, i.e., the annual increment between 6-7 and 7-8 age groups represent the increment at 7 year.

TABLE 4

Hand length (cm)

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	14.15	0.82	14.11	0.83	24	13.93	0.80	13.92	0.78
7 - 8	57	14.67	0.81	14.63	0.83	34	14.31	0.81	14.26	0.78
8 - 9	36	15.19	0.84	15.14	0.88	38	14.89	0.96	14.83	0.90
9 - 10	28	16.02	0.96	15.96	0.92	27	15.80	0.92	15.77	0.94
10 - 11	26	16.29	0.90	16.35	0.85	30	15.98	0.80	15.95	0.77
11 - 11.5						32	17.00	0.92	17.03	0.95
11.5 - 12	31	16.68	0.99	16.75	0.95	33	17.25	1.05	17.25	1.02
12 - 12.5	30	17.15	0.86	17.21	0.85	34	17.26	0.95	17.25	0.94
12.5 - 13	32	17.72	0.90	17.73	0.89	34	17.93	0.82	17.96	0.81
13 - 13.5	33	18.25	1.11	18.27	1.05	33	18.12	0.86	18.11	0.84
13.5 - 14	33	18.65	0.88	18.69	0.89	33	18.13	1.00	18.08	0.97
14 - 14.5	35	19.64	0.99	19.66	0.99	33	18.35	0.82	18.38	0.80
14.5 - 15	33	19.68	0.79	19.71	0.84	35	18.08	0.85	18.12	0.83
15 - 15.5	32	19.59	0.86	19.70	0.82	33	17.97	0.78	18.11	0.80
15.5 - 16	32	19.83	1.07	19.87	1.10	31	18.16	0.72	18.18	0.70
16 - 17	30	20.00	0.85	20.03	0.89	32	18.48	0.68	18.52	0.70
17 - 18	32	20.04	0.88	20.09	0.81	34	18.46	0.66	18.45	0.63

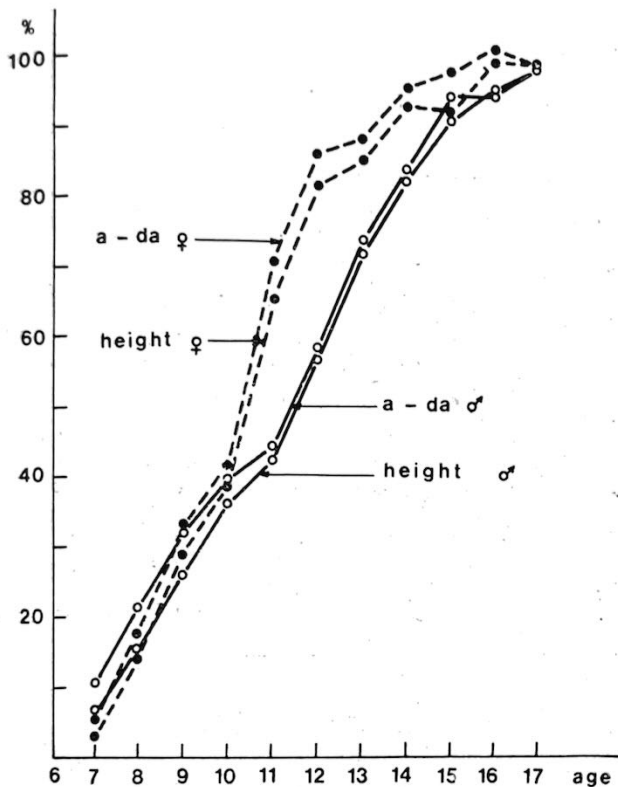


FIG. 4. Cumulative relative increments for height and total arm length.

RESULTS

As we did not find any significant differences between measures for right and left side of the body data for right limb are presented only in what follows.

Sample sizes for each age and sex category, means and standard deviations for each measure mentioned in Methods are presented in tables 1-

through 12 given in the text of this paper. As the distance curves follow usual trends they will be described only briefly in the following text. Detailed description of these data may be found in my thesis (Škvařilová 1974).

Briefly, the total arm length and lengths of its segments follow closely the curve of body height. Increasing and parallel trend of boys' and girls' distance curves (boys are little ahead of girls) from the beginning of the analysed period is interrupted in approximately 11 years when girls overtake the boys' curve due to its earlier adolescent spurt. This period of girl's superiority in length measures of the upper limb is completed close to 14 years. Then boys are again ahead of girls and their curve is still slightly increasing while that of girls remains relatively flat.

Breadth dimensions resemble this pattern. The only exception is that adolescent spurt is a little less pronounced and this is the reason that boys are permanently ahead of girls.

A little different picture show circumference measures. As the arm circumference is concerned the girls' distance curve is permanently above that of boys only at the end of period studied (from about 15 years) the boys overhauled the girls. Other circumferences of the upper limb resemble the pattern of breadth measures.

Velocity curves for height, total arm length and the lengths of its segments are shown in Fig. 1. It can be seen again that gains of total arm length parallel closely those of body height. The same seems to be valid even for its segments. Just prior the adolescent spurt there is a more or less pronounced pre-adolescent slowing of growth, in boys between 9-11 and in girls in about 10 years. Following spurt (in girls around 11, in boys between 12-14 years) is much more pronounced in girls

TABLE 5

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	51.41	2.79	51.36	2.61	24	51.17	2.14	50.87	2.56
7 - 8	57	53.00	3.32	52.91	3.62	34	51.94	3.53	51.94	3.83
8 - 9	36	54.33	3.50	54.39	3.27	38	52.92	2.54	52.97	2.58
9 - 10	28	56.39	2.88	56.18	2.82	27	54.39	3.09	54.30	3.07
10 - 11	26	59.15	2.56	59.19	2.53	27	56.15	3.15	56.19	3.31
11 - 11.5	31	60.97	2.55	61.03	2.61	30	59.25	3.67	58.84	3.41
11.5 - 12	30	63.07	3.32	62.97	3.33	32	60.03	3.46	59.73	3.22
12 - 12.5	32	65.13	4.15	64.78	4.06	33	60.65	3.03	60.38	2.77
12.5 - 13	33	67.85	4.06	67.15	4.06	34	62.15	2.92	61.62	2.98
13 - 13.5	33	68.39	4.11	67.97	4.07	33	63.30	3.56	62.82	3.92
13.5 - 14	35	70.54	3.07	70.31	3.13	33	61.76	2.66	61.58	2.35
14 - 14.5	33	71.30	3.42	71.45	3.16	33	63.00	2.74	63.00	2.93
14.5 - 15	32	72.00	3.30	71.91	3.51	33	62.29	2.93	62.17	2.86
15 - 15.5	32	72.75	3.42	72.38	3.11	35	62.30	3.61	62.24	3.61
15.5 - 16	30	73.40	3.13	72.77	3.65	33	63.58	3.03	63.32	3.02
16 - 17	32	73.50	3.27	73.34	3.65	31	63.53	2.76	63.53	2.98
17 - 18	32					34	61.59	2.43	61.71	2.47

TABLE 6

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	42.95	2.13	42.59	2.08	24	42.00	2.38	41.54	1.93
7 - 8	57	43.42	2.46	43.54	2.28	34	42.29	2.34	42.35	2.31
8 - 9	36	44.17	2.79	44.03	2.82	38	43.10	2.47	43.05	2.36
9 - 10	28	45.50	2.24	45.57	2.03	27	43.96	2.53	44.13	2.67
10 - 11	26	48.04	1.99	48.12	1.82	30	46.08	2.95	45.85	3.00
11 - 11.5	31	48.97	2.39	48.90	2.36	32	47.94	2.55	48.13	2.26
11.5 - 12	30	50.33	2.63	50.27	2.90	33	49.24	3.00	49.00	3.05
12 - 12.5	32	51.22	3.66	50.94	3.49	34	48.56	1.87	48.65	2.07
12.5 - 13	33	53.79	3.61	53.27	3.65	34	50.15	2.57	50.15	2.49
13 - 13.5	33	54.88	3.58	54.45	3.65	33	49.91	2.65	49.76	2.79
13.5 - 14	35	56.80	2.93	56.37	2.88	33	50.45	2.53	50.24	2.65
14 - 14.5	33	57.27	3.33	56.91	3.21	33	51.30	2.59	51.21	2.37
14.5 - 15	32	57.81	2.61	57.38	2.59	35	50.69	2.90	50.49	2.74
15 - 15.5	32	57.66	2.83	57.31	2.76	33	50.88	2.77	50.12	2.53
15.5 - 16	30	57.50	2.83	56.60	2.86	31	51.06	2.43	50.74	2.24
16 - 17	32	57.63	2.53	56.81	2.68	32	51.69	2.47	51.13	2.41
17 - 18	32					34	50.85	2.35	50.53	2.17

but in boys is of longer duration (2 years comparing with only 1 year in girls). Then in boys follows slow decrease of growth rate to the end of the analysed period. The fall in girls is much more steep and of short duration. Then the growth in girls seems to be completed. A slight difference may be seen in the forearm length where we found in boys one year period of pre-adolescent slowing only.

Breadth measures velocity curves (Fig. 2) resemble this general pattern. Pre-adolescent slowing lasts in boys approximately one year only, however, in comparison with two-years period in length measures and is shifted to about 11 years. The

decrease following the adolescent spurt in boys is consistently longer and even the spurt itself is of longer duration of approximately 3 years (12-14).

Different pattern of growth may be seen in circumference measures of the upper limb the velocity curves of which are shown in Fig. 3. Pre-adolescent slowing lasts one year in boys and girls only and is situated close to 11 years. Just prior this slowing (in approximately 10 years) the curves peak again both for boys and girls. The resting part of the curves resemble the general pattern of length dimensions.

The mutual comparison of growth rates of different measures of the upper limb in this study is

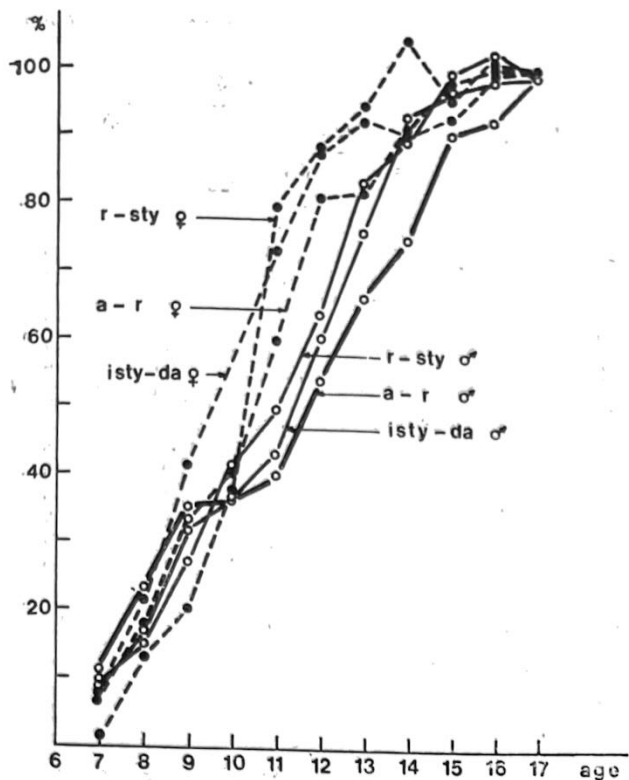


FIG. 5. Cumulative relative increments for the lengths of segments of the upper limb.

made through either the curves of cumulative increments or various indexes (see Methods). These former for length measures are plotted in Figs 4 and 5. It is clear from these figures that starting from approximately 10 years (girls' spurt) girls are permanently ahead (close to the total increment, i.e. to the adult value) of boys and only at the end of the analysed period are overhauled by boys. After more detailed inspection it may be seen that height, total arm and hand length curves have similar shape and are ahead of all. This latter statement is a little bit different within the girls where both hand and forearm are more advanced.

In breadth relative gains (Fig. 6) girls are ahead of boys even earlier, from about 9 years, but comparing individual breadth measures for particular sex there are no apparent differences.

In circumference measures (Fig. 7 and 8) girls are again ahead of boys from approximately 9–10 years. Here the forearm is ahead of arm and hand while the wrist is ahead of all.

$$\text{Indexes} \frac{\text{total arm length}}{\text{height}} \times 100 \text{ and}$$

$$\frac{\text{total arm length}}{\text{sitting height}} \times 100$$

for boys and girls (Fig. 9 and 10) are relatively flat (the first index) or slowly increasing (the second index). Only in between 12 and 13 years there is a local decrease preceded by small increase in girls only. In the case of the first index it may be interpreted that total arm length and height of the body grow in a closely similar manner only during the adolescent spurt growth rate of height is prevailing.

In the second index increasing trend from the very beginning implies higher growth rate of the upper limb. Comparing with the previous index it reflects the well-known fact that the increase in body height is given mainly through the length of the lower extremities. Small decrease between 12 and 13 years seems to result from the same reason as explained in the case of the first index. Then the curves for both sexes are flat.

In brachial index (Fig. 11) there is a permanent decrease both in boys and girls from the very beginning to a minimum close to 9–10 years (this implies higher growth rate of the upper arm) followed by a steep increase to about 12–13 years (growth rate of the forearm prevailing). After short decrease around 13 years the index is relatively constant and from about 15 years slowly decreases.

Index $\frac{\text{hand breadth}}{\text{hand length}} \times 100$ (Fig. 12) decreases in both boys and girls to about 9–10 years. Then in boys the curve remains relatively flat in girls slow decrease continues to the end of the analysed period.

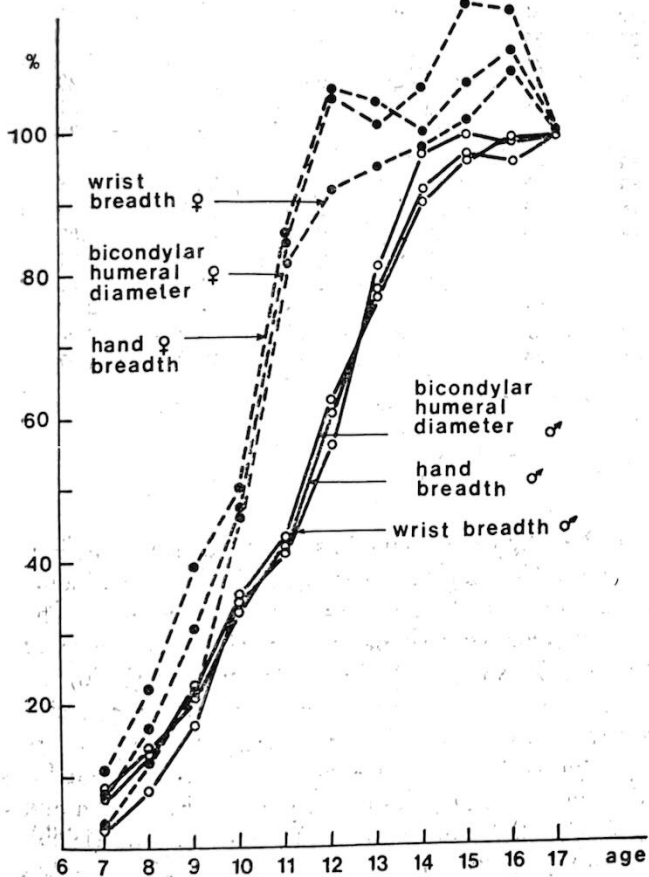


FIG. 6. Cumulative relative increments for breadth measures of the upper limb.

DISCUSSION

As mentioned in the Introduction there is a relative lack of data concerning the growth and

TABLE 7

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	61.68	3.05	61.36	2.98	24	60.58	2.32	60.04	2.01
7 - 8	57	63.60	3.49	63.25	3.58	34	62.06	2.84	61.68	2.96
8 - 9	36	65.05	3.61	64.78	3.63	38	63.60	3.26	63.34	3.22
9 - 10	28	66.79	3.69	66.29	3.43	27	65.87	3.55	65.48	3.63
10 - 11	26	69.50	2.98	69.27	3.18	30	67.35	3.59	66.88	3.42
11 - 11.5	31	71.42	3.34	70.97	3.29	32	71.06	4.89	70.34	4.77
11.5 - 12	30	72.80	5.03	72.50	4.80	33	72.12	4.48	71.42	4.47
12 - 12.5	32	75.97	4.80	75.41	4.71	34	72.76	3.85	72.15	3.55
12.5 - 13	33	78.76	5.05	78.03	4.77	34	74.97	4.21	74.47	4.11
13 - 13.5	33	79.85	5.20	78.97	5.11	33	75.18	3.99	74.64	4.18
13.5 - 14	33	83.83	4.38	82.94	4.24	33	74.73	3.42	74.09	3.10
14 - 14.5	33	83.33	4.56	82.61	4.01	33	74.76	3.24	74.45	3.10
14.5 - 15	32	83.72	4.10	82.75	4.16	35	74.17	3.55	73.80	3.67
15 - 15.5	32	84.50	3.95	83.72	3.77	33	74.58	3.48	73.88	3.27
15.5 - 16	30	84.20	3.70	83.10	3.65	31	75.10	3.48	74.35	3.59
16 - 17	32	85.16	3.90	84.25	3.81	32	75.78	2.98	75.13	2.77
17 - 18	32					34	74.09	2.93	73.50	3.05

TABLE 8

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	18.25	1.90	18.26	2.06	24	19.61	1.89	19.54	1.88
7 - 8	57	19.16	2.01	19.12	2.00	34	19.20	2.24	19.15	2.43
8 - 9	36	19.53	1.91	19.45	1.89	38	19.86	1.64	19.80	1.62
9 - 10	28	19.98	2.39	19.96	2.34	27	20.02	2.32	19.99	2.32
10 - 11	26	20.96	1.97	20.94	1.99	30	21.70	3.03	21.36	3.26
11 - 11.5	31	21.00	2.07	20.93	2.09	32	22.01	2.26	21.96	2.23
11.5 - 12	30	22.68	2.70	22.67	2.67	33	22.11	2.28	22.05	2.21
12 - 12.5	32	22.63	2.64	22.60	2.64	34	23.22	2.34	23.23	2.37
12.5 - 13	33	23.86	2.90	23.82	2.89	34	23.59	2.66	23.59	2.65
13 - 13.5	33	23.98	2.73	23.87	2.75	33	24.61	2.97	24.57	2.98
13.5 - 14	33	24.77	2.34	24.74	2.38	33	24.26	2.60	24.23	2.63
14 - 14.5	35	25.20	2.20	25.15	2.17	33	25.28	3.47	25.24	3.50
14.5 - 15	32	25.72	2.63	25.63	2.63	35	25.28	2.74	25.26	2.71
15 - 15.5	32	25.92	2.39	25.86	2.39	33	25.61	2.51	25.55	2.50
15.5 - 16	30	26.60	2.07	26.54	2.07	31	25.03	2.09	24.97	2.13
16 - 17	32	28.00	2.10	27.88	2.08	32	25.28	2.13	25.31	2.09
17 - 18	32					34	24.46	1.76	25.43	1.67

development of the total complex of individual segments of the upper limb in school age children. In our literature Lišoněk and Hrněič (1960) presented the standards of total arm length (projective measures) for school age Moravian children. Means in both sexes are consistently lower comparing with our results. Similar standards for Munich school age children published by Martin and Saller (1959) show the same picture, i.e. arms of our children are longer. On the other hand data available for Bulgarian children (Yanev et al. 1965) show absolutely and relatively (to the height) longer upper limb.

As the upper arm and forearm lengths are con-

cerned comparable data has been published in Pařízková's longitudinal study (1972) on Prague boys. Her results are close to our findings. The same is true comparing our results with those of Borovanský and Hněvkovský (1930).

Hand length was measured from the dorsal side in this study. Jelínek's data on Greek children are consistently lower. The same seems to be valid for both some American studies (cited in Martin and Saller 1959) or data of Yanev et al. (1965). Zrzavý (1964) and Hajniš (1969) presented findings which resemble ours more closely.

Values of bicondylar humeral diameter given for American children by Meredith (1935) and

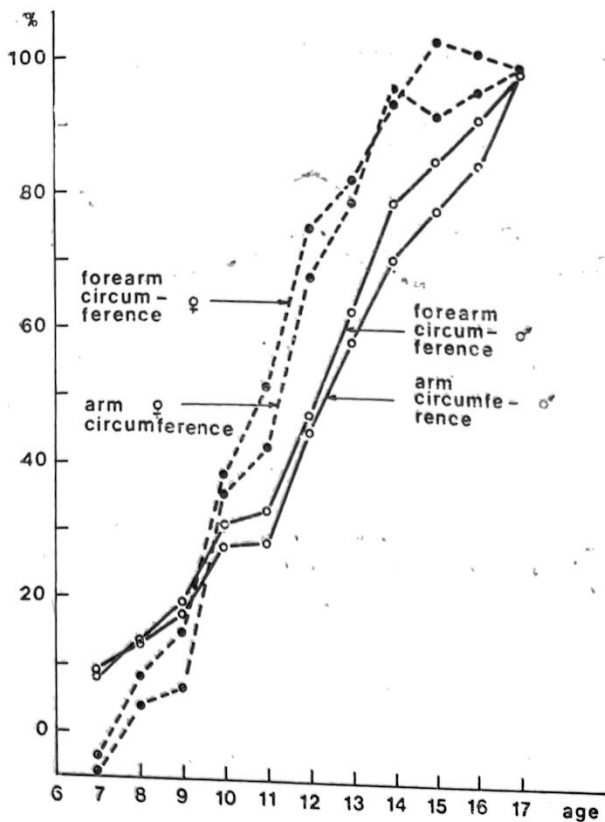


FIG 7. Cumulative relative increments for the forearm and arm circumferences.

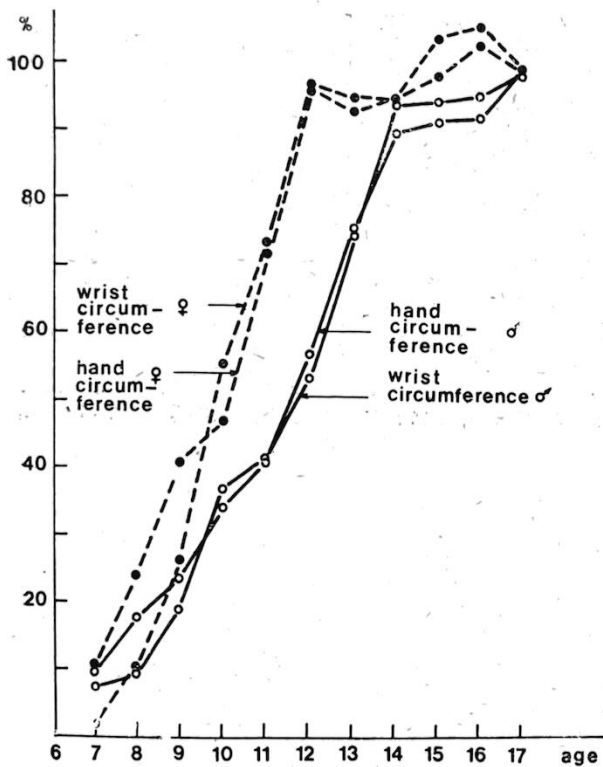


FIG. 8. — Cumulative relative increments for the wrist and hand circumferences.

Boynton (1936) are similar to our findings (differences 1–3 mm). Wrist breadth was followed in Prague children by Jägrová (1966) and Šimůnková (1966) and their measurements result in higher values. Differences might be explained through different age grouping, different measuring methods used etc. Hand breadth in Greek children (Jelínek 1950) does not differ from our study. Little higher values of this measure presented for Prague children by Hajniš (1969) might again be influenced by factors mentioned above.

Higher amounts of subcutaneous fat in girls from about 5–6 years (Tanner 1962) result in the fact that girls are ahead of boys from approximately 9 years. Comparing our arm circumferences with other studies, Borovanský and Hněvkovský (1930), Martin and Saller (1959), Yanev et al. (1965) and Machová (1970) presented data which are either similar or slightly lower than ours. The same is true for Pařízková's data (1972). Our wrist and hand circumferences correspond closely to the values of Jägrová (1966) and Šimůnková (1966). Second peak in circumferences velocity curves reflects presumably the process of accumulation of the subcutaneous fat just prior to the adolescent spurt.

Our finding that the forearm length is ahead of other segments of the upper limb in boys seems not to agree with the well-known gradients operating within the limbs. Tanner (1962) states that the distal segments of the limbs are ahead of the proximal ones at all ages and this feature is independent of the sex differences. Perhaps our result might be an artefact of purely cross-sectional study while Tanner data are based on mixed longitudinal sample. Our girls' data which resemble exactly this Tanner's scheme seems to provide strong support for this explanation.

On the other hand the existence of this gradients implies that from some age the hand length growth rate would be smaller. This was observed by Borovanský and Hněvkovský (1930) and our findings support this as well.

ABSTRACT

Standards for the growth of the upper limb and of its segments are presented for normal males and females aged six through eighteen years. Using conventional measuring methods means and standard deviations for 13 length, breadth and circumference measures, annual absolute and relative (cumulative) increments were determined.

Velocity curves for length measures in both boys and girls follow closely the trend of body height. Adolescent spurt is preceded by two (in boys) or one year (in girls) period of preadolescent slowing. Girls are ahead of boys from their spurt to about 14 years. Hand is most advanced in girls whereas forearm in boys. In breadth measures girls are ahead of boys even earlier (from 9 years) and individual parts show the similar growth pattern. Velocity curves for circumference measures show

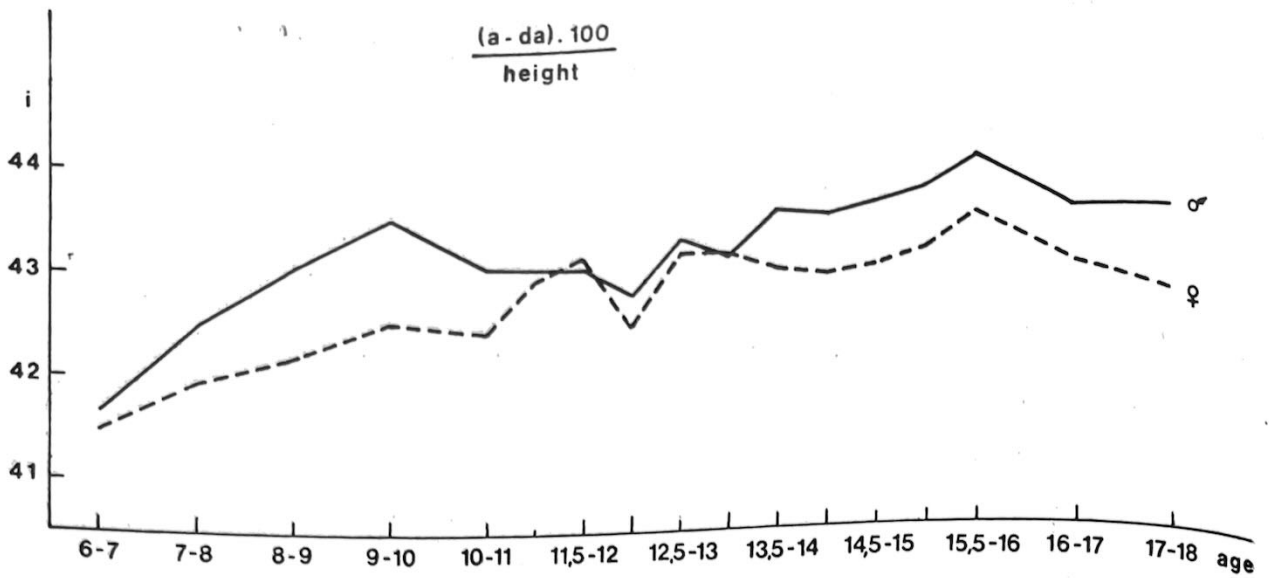


FIG. 9. Distance curves for index $\frac{\text{total arm length}}{\text{height}} \times 100$

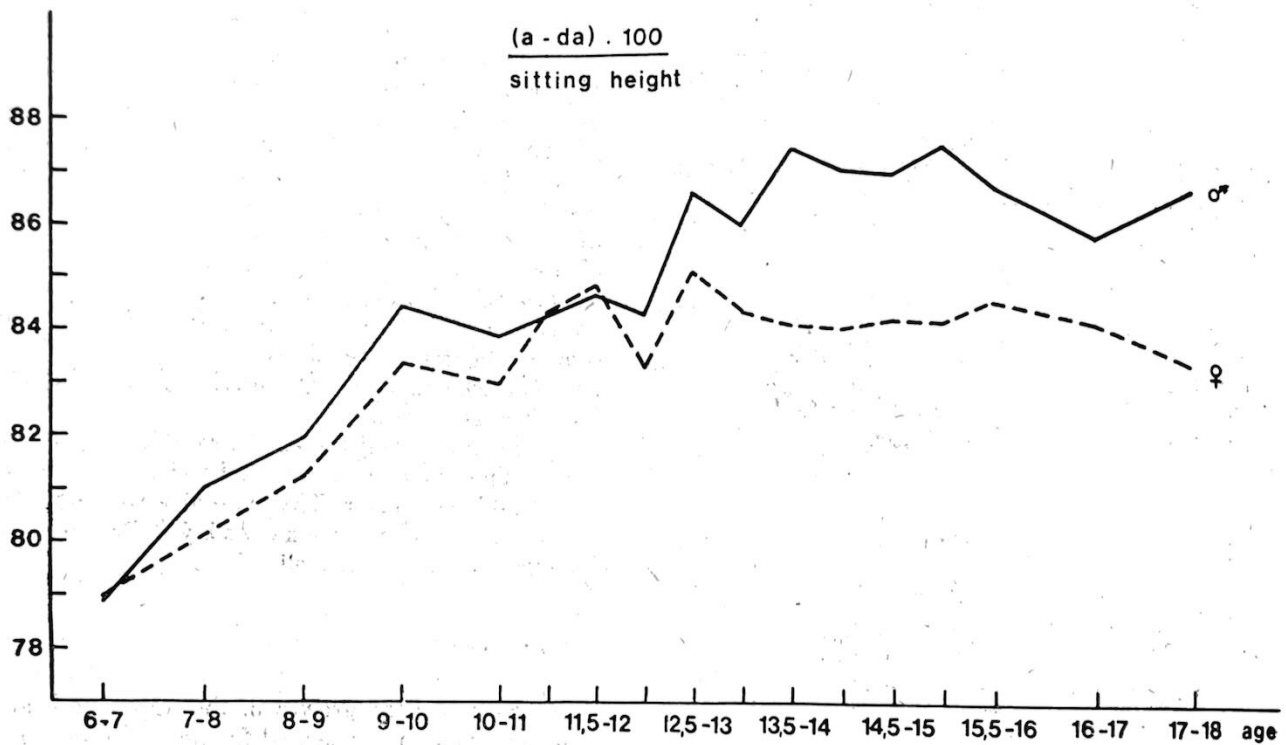


FIG. 10. Distance curves for index $\frac{\text{total arm length}}{\text{sitting height}} \times 100$

second peak prior to the usual adolescent spurt. This presumably reflects the accumulation of subcutaneous fat preceding the spurt. Girls are ahead of boys from about 10 years and the wrist and forearm are more advanced.

ACKNOWLEDGMENTS

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TABLE 9

Forearm circumference (cm)

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	18.20	1.55	18.13	1.38	24	18.76	1.23	18.63	1.22
7 - 8	57	18.90	1.60	18.90	1.60	34	18.60	1.77	18.60	1.78
8 - 9	36	19.27	1.39	19.26	1.40	38	19.13	1.06	19.14	1.07
9 - 10	28	19.72	1.36	19.70	1.37	27	19.41	1.44	19.37	1.42
10 - 11	26	20.63	1.25	20.65	1.28	30	20.45	1.79	20.43	1.83
11 - 11.5	31	20.81	1.82	20.83	1.45	32	20.92	1.49	20.89	1.45
12 - 12.5	30	21.84	1.82	21.80	1.79	33	21.04	1.37	21.04	1.35
12.5 - 13	32	21.99	1.80	21.95	1.75	34	21.70	1.55	21.68	1.57
13 - 13.5	33	22.99	1.68	22.93	1.64	34	22.08	1.56	22.08	1.57
13.5 - 14	33	23.22	1.86	23.10	1.89	33	22.64	1.70	22.60	1.72
14 - 14.5	35	24.27	1.46	24.25	1.43	33	22.40	1.20	22.42	1.25
14.5 - 15	33	24.50	1.56	24.34	1.61	33	23.17	1.95	23.08	1.92
15 - 15.5	32	24.79	1.82	24.70	1.74	35	22.94	1.56	22.91	1.50
15.5 - 16	32	25.03	1.61	24.94	1.56	33	23.20	1.37	23.14	1.37
16 - 17	30	25.50	1.44	25.37	1.42	31	23.34	1.42	23.30	1.40
17 - 18	32	26.10	1.38	26.00	1.28	32	23.27	1.34	23.26	1.28
						34	23.16	1.27	23.08	1.25

TABLE 10

Wrist circumference (cm)

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	13.14	1.04	13.25	0.92	24	13.04	0.84	13.00	0.82
7 - 8	57	13.43	0.92	13.42	0.90	34	13.08	0.95	13.07	0.97
8 - 9	36	13.51	1.00	13.63	0.91	38	13.26	0.71	13.24	0.72
9 - 10	28	13.86	0.77	13.90	0.79	27	13.63	0.88	13.58	0.81
10 - 11	26	14.60	0.74	14.59	0.71	30	14.29	1.04	14.23	1.06
11 - 11.5	31	14.77	0.83	14.70	0.77	32	14.55	0.83	14.55	0.85
11.5 - 12	31	14.77	0.83	14.70	0.77	33	14.70	0.91	14.66	0.88
12 - 12.5	30	15.17	0.89	15.14	0.89	34	14.89	0.68	14.92	0.72
12.5 - 13	32	15.25	0.97	15.16	0.98	34	15.24	0.79	15.23	0.76
13 - 13.5	33	15.86	0.98	15.82	0.99	33	15.30	0.91	15.24	0.95
13.5 - 14	33	16.09	1.07	16.01	1.09	33	15.19	0.67	15.18	0.68
14 - 14.5	35	16.79	0.72	16.69	0.72	33	15.54	0.94	15.55	0.92
14.5 - 15	33	16.86	0.79	16.85	0.76	35	15.19	0.78	15.21	0.79
15 - 15.5	32	16.94	0.86	16.83	0.89	33	15.33	0.70	15.28	0.72
15.5 - 16	32	16.87	0.68	16.87	0.69	31	15.40	0.70	15.37	0.72
16 - 17	30	16.91	0.75	16.79	0.68	32	15.45	0.71	15.44	0.66
17 - 18	32	17.06	0.61	17.01	0.60	34	15.29	0.58	15.28	0.57

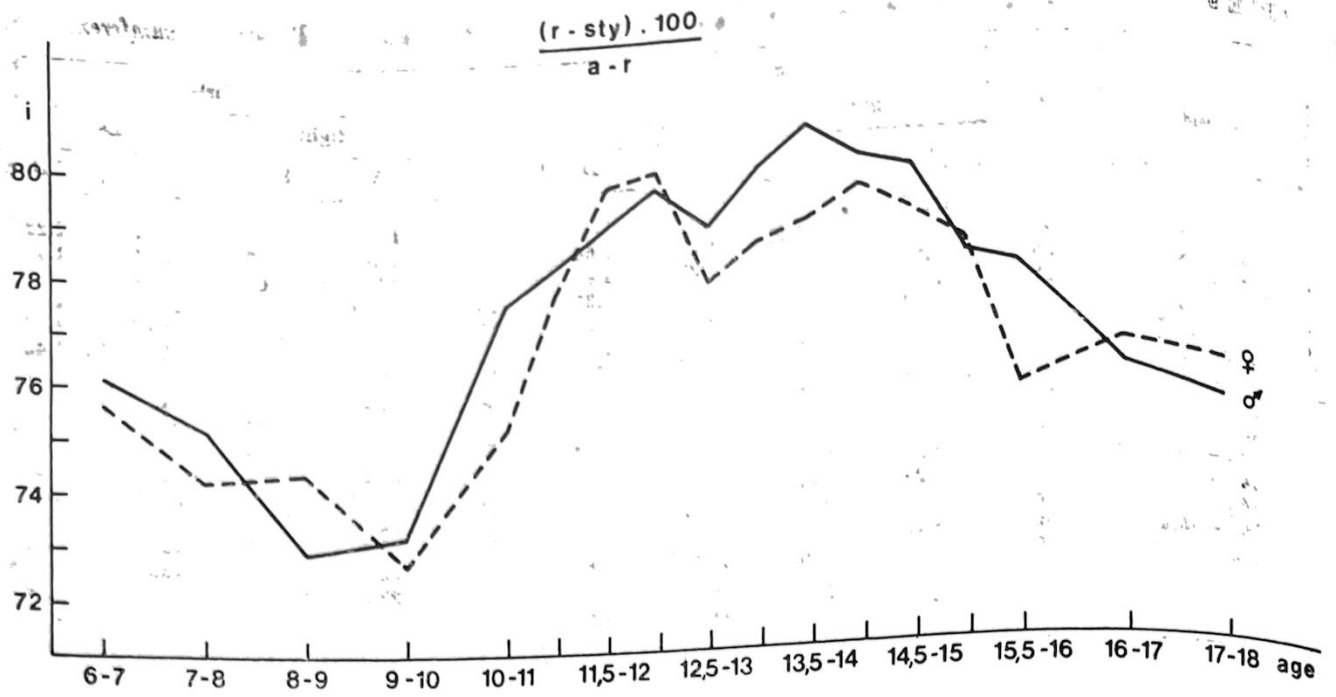


FIG. 11. Distance curves for brachial index.

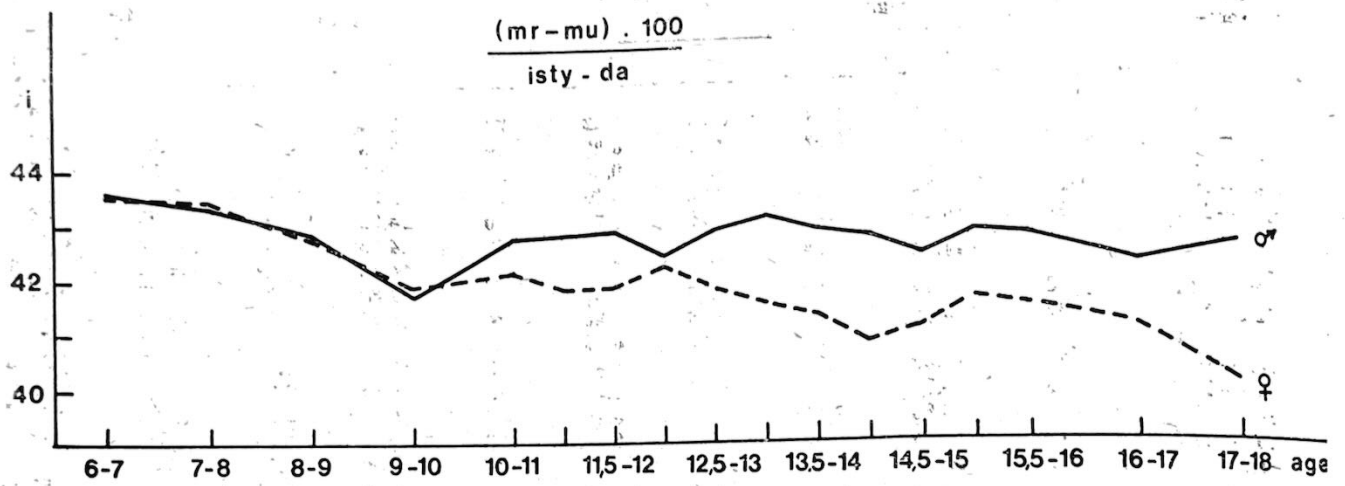


FIG. 12. Distance curves for index $\frac{\text{hand breadth}}{\text{hand length}} \times 100$

TABLE 11

Hand circumference (cm)

Age groups	n	Boys				n	Girls			
		Right		Left			Right		Left	
		\bar{x}	S.D.	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.
6 - 7	22	15.35	1.02	15.54	0.86	24	15.12	0.66	15.13	0.64
7 - 8	57	15.92	0.82	15.89	0.82	34	15.47	0.93	15.46	0.90
8 - 9	36	16.36	1.00	16.30	0.95	38	15.93	0.85	15.86	0.87
9 - 10	28	16.70	0.91	16.64	0.89	27	16.50	0.92	16.42	0.92
10 - 11	26	17.31	0.74	17.28	0.76	30	16.70	0.91	16.67	0.91
11 - 11.5	31	17.72	0.87	17.71	0.91	32	17.59	1.11	17.50	1.12
11.5 - 12	30	18.21	1.01	18.10	0.96	33	17.55	0.97	17.49	0.97
12 - 12.5	32	18.60	1.08	18.53	1.05	34	17.93	0.83	17.87	0.85
12.5 - 13	33	19.31	1.17	19.22	1.04	34	18.42	0.90	18.30	0.89
13 - 13.5	33	19.70	1.24	19.55	1.25	33	18.52	1.10	18.39	1.08
13.5 - 14	35	20.71	1.03	20.56	1.00	33	18.29	0.87	18.22	0.82
14 - 14.5	33	20.53	1.16	20.44	1.05	33	18.45	0.82	18.43	0.81
14.5 - 15	32	20.72	0.93	20.56	0.90	35	18.35	0.90	18.25	0.90
15 - 15.5	32	20.64	0.83	20.54	0.82	33	18.47	0.76	18.31	0.74
15.5 - 16	30	20.68	0.82	20.54	0.85	31	18.48	0.74	18.36	0.79
16 - 17	30	21.08	1.01	20.93	0.98	32	18.64	0.77	18.52	0.73
17 - 18	32					34	18.50	0.75	18.33	0.77

TABLE 12

Age groups	Height (cm)						Sitting height (cm)					
	n	Boys		n	Girls		n	Boys		n	Girls	
		\bar{x}	S.D.		\bar{x}	S.D.		\bar{x}	S.D.		\bar{x}	S.D.
6 - 7	22	124.00	6.09	24	126.17	5.03	22	65.52	3.43	24	66.28	2.00
7 - 8	57	128.01	5.29	34	127.43	6.13	57	67.18	2.51	34	66.70	2.89
8 - 9	36	132.27	6.13	38	131.91	5.44	36	69.49	3.05	38	68.47	2.77
9 - 10	28	138.17	7.14	27	137.82	6.48	28	71.14	2.96	27	70.18	2.74
10 - 11	26	143.92	5.03	30	141.86	6.88	26	73.78	2.50	30	72.59	2.49
11 - 11.5	31	147.25	5.65	32	150.37	6.49	31	74.71	2.34	32	76.45	3.55
11.5 - 12	30	152.69	7.64	33	152.58	6.67	33	77.36	3.08	33	77.48	3.58
12 - 12.5	32	155.67	6.77	34	154.27	6.38	30	77.77	3.38	34	78.63	3.68
12.5 - 13	33	160.57	7.28	34	159.06	5.70	32	77.77	3.38	34	80.62	3.31
13 - 13.5	33	164.09	8.03	33	160.42	5.16	33	80.46	3.85	33	82.10	3.73
13.5 - 14	33	164.09	8.03	33	160.58	6.31	33	81.64	4.00	33	82.05	3.75
14 - 14.5	35	170.69	7.28	33	164.33	6.41	35	85.26	4.00	33	84.02	4.24
14.5 - 15	33	170.00	6.74	35	163.98	5.06	33	85.25	3.93	35	83.71	2.83
15 - 15.5	32	173.64	6.58	33	163.20	5.43	32	86.87	4.37	33	83.57	2.62
15.5 - 16	32	174.85	7.74	31	163.34	5.40	32	88.81	4.15	31	84.01	2.92
16 - 17	30	177.10	6.34	32	166.52	5.38	30	89.95	3.49	32	85.21	2.82
17 - 18	32	179.34	7.58	34	166.39	5.18	32	90.30	3.20	34	85.47	2.76

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