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SOMATIC DEVELOPMENT AND BODY COMPOSITION CHANGES IN ADOLESCENT BOYS DIFFERING IN PHYSICAL ACTIVITY AND FITNESS: A LONGITUDINAL STUDY

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I. INTRODUCTION

Optimal growth and development in childhood and adolescence has become a topic of interest not only to pediatricians and medical people in general, but also to physiologists, human biologists, anthropologists, and many others. There are still areas in the world where meeting children's nutritional, and hygienic needs is an urgent problem. On the other hand, in highly developed industrialised countries where these needs are mostly assured, other problems appear, among them the very low level of physical fitness in children and adolescents, the high incidence of obesity, disturbances in body posture and orthopedic defects.

The advantages and transport facilities of contemporary life, especially in great cities represent comfort, but they may not be optimal for the child; indeed, lack of physical activity during the growth period could even be harmful.

Comparisons of subjects who are active and inactive in sports confirm that physical activity and exercise are basically beneficial. But such comparisons do not establish what comes first — that is, whether exercise leads to better health or whether healthier and more fit subjects are more likely to participate in systematic physical exercises.

The influence of physical exercise on somatic development has been studied (Schwartz et al., 1928; Arnold, 1930; Correnti, 1941; Tanner, 1952 etc.) but most of the studies are cross-sectional or of short duration only (several months). They cannot differentiate dependably the influence of hereditary and constitutional factors, seasonal influences, social background, etc. from the true consequences of increased physical activity and sports.

Also, there are certain periods during which the organism is specially sensitive to various stimuli, both positive and negative. Consequently, it is important to know the age at which the increased physical activity is started, the intensity and nature of the activity, and its duration. Almost unknown are the delayed consequences of increased physical activity for adult and advanced age.

It is obvious that the exact character of somatic developmental changes due to physical activity during growth can be elucidated best by longitudinal studies, but even in this case some influence of constitutional and genetic background can not be completely excluded (preference for exercise, adherence to long-term training programs). The possible and the whole complex of anthropometric characteristics suitable for physical fitness evaluation ought to be measured. Then it can be shown how children who engage systematically in intensive physical exercise grow in comparison with those who do not.

The main aim of our investigation was to study somatic development of normal healthy adolescent boys (approximately from 11 to 18 years, when spontaneous interest in physical exercise and sport is high) engaged in different types of physical activity. Changes in body composition (i.e. lean body mass and depot fat) and their relations to other somatic characteristics have been stressed in view of the close relationship between body composition and the functional state of the organism (Behnke, 1956; Brožek, 1954; Pařízková, 1962; 1966c).

II. CHARACTERISTIC OF EXPERIMENTAL SUBJECTS

We started our longitudinal study in 1961. The original group ($n = 143$) was subdivided into three subgroups: boys who were just starting the training in sport schools of light athletics ($n = 43$) and basketball ($n = 39$), and the control group of boys who except for physical education at school, were not involved in systematic sport activities ($n = 61$). The subjects were chosen on the basis of thorough medical examination. Only those with good health were included. Boys with markedly accelerated or retarded somatic development (from the point of view of height, weight, chest circumference, skeletal age) were eliminated.

The subjects lived in a city of one million of inhabitants, with good transportation facilities. They attended the same type of public schools; their parents had approximately the same income (middle and lower middle class). All subjects lived with their families under adequate nutritional and hygienic conditions. Physical activity has been the most important variable differentiating the experimental groups.

When after the first three years of study the data concerning morphological and functional development were compared, no significant differences were found (P a ř í z k o v á, 1964; Š p r y n a r o v á, 1966). This did not come as a surprise since we knew that the physical activity regimen changed considerably in comparison with the pattern characterizing the first year. Many of the "active" boys either interrupted their activities in the sport schools or changed sports, while some boys from the control group started some physical exercise in the course of these years. The boys collaborated with us on a voluntary basis and there we could not force them either to go on with the original sport activity when it was no more interesting for them, or to forbid others to begin some sport activity.

From the first until eighth year the subjects actual sport activities were examined regularly by means of a questionaire and by reviewing their participation in sport club activites. The subjects were regrouped after eight years into three groups according to the overall time spent in systematic physical exercise. Only subjects who were followed in all eight years were considered. This reduced the total group to 41 boys, what changed in part the composition of our subgroups in comparison with those formed in 1961.

The three subgroups were defined as follows: subgroup I ($n = 10$) boys who trained regularly during the whole period of 8 years in sport schools. This amounted to more than six hours of organised intensive regular physical exercice per week. Moreover these boys participated individually in some additional unorganised sport activity. In addition, the subjects participated regularly in special summer camps of four weeks duration until fifteen years. Subgroup II ($n = 18$) boys who trained regularly in the sport schools during five years and then continued in training till the last year. In the mean they had 4 hours of organised regular exercise per week. Subgroup III ($n = 13$) boys with limited sport activity lasting less than two hours and a half per week, including physical education at school.

The differences in the physical activity of the three subgroups were quantitative only. It was not possible to find among healthy boys subjects who do not engage in any physical exercise and use them as a control group. In group I the general physical activity was relatively intensive and systematic, and it was relatively low in group III with the other group being intermediary in this respect.

III. METHODS AND PROCEDURES

All measurements and clinical examinations were performed always in the spring, mostly in April and May. Those who had become seriously ill were excluded. Those who were just recovering from illness or had a cold were invited for a clinical reexamination at a later period. All measurements and tests were thus made in state of good health. Somatic measurements, roentgenography, and functional tests were all completed within a period of 3 to 8 days.

The anthropometric dimensions described by M a r t i n (1928) and T a n n e r (1962; 1964) included: height; weight; sitting height; length of the upper and lower extremities and their segments; circumference of the arm during muscle contraction and relaxation on the right and left sides; circumferences of the forarm, thigh and calf on both sides; breadth measures of the trunk — biacromial, bicristal, and bitrochanteric diameters; chest breadth and depth; circumferences of the chest at rest, expiration and inspiration; breadth of the wrist and femoral condyles as indicators of the robusticity of the skeleton.

Further selected derived values were calculated, which enabled to characterise body build and proportionality, and also in certain respects the functional state of the organism. E.g. relative dimension

$$\frac{\text{chest circumference expir.} \times 100}{\text{chest circumference inspir.}}$$

or the difference between the value of chest circumference at inspiration and expiration can characterise indirectly the respiratory capacity of the thorax. Relative dimension

$$\frac{\text{arm circumference relax.} \times 100}{\text{arm circumference contr.}}$$

can indirectly serve as an indicator of the functional state of the muscles involved better than simple absolute circumferential measures. Relative dimension

$$\frac{\text{sitting height} \times 100}{\text{height}}$$

characterises the relative length of the trunk and the lower extremities. Relative dimensions

$$\frac{\text{biacromial breadth} \times 100}{\text{height}}$$

$$\frac{\text{bicristal breadth} \times 100}{\text{height}}$$

$$\frac{\text{bicristal breadth} \times 100}{\text{biacromial breadth}}$$

$$\frac{\text{bitrochanteric breadth} \times 100}{\text{height}}$$

$$\frac{\text{bitrochanteric breadth} \times 100}{\text{biacromial breadth}}$$

$$\frac{\text{chest breadth} \times 100}{\text{biacromial breadth}}$$

$$\frac{\text{chest circumference} \times 100}{\text{height}}$$

characterise the relative breadth of the trunk and body build, as well as the relative dimensions

$$\frac{\text{calf circumference} \times 100}{\text{thigh circumference}}$$

and

$$\frac{\text{forarm circumference} \times 100}{\text{arm circumference}}$$

express the proportionality of proximal and distal segments in the extremities.

Body composition was calculated from body density as described by Brožek et al. (1949), Keys and Brožek (1953) and Brožek (1954). Body volume was ascertained by hydrostatic weighing, with simultaneous measurement of the air contained in the lungs and respiratory passages; we used the nitrogen dilution method (Cournand et al., 1940; 1941), modified for using an interferometer (Navrátil et al., 1958) and adapted in our laboratory to measurements made during underwater weighing (Pařízková, 1959; 1961; 1962). Relative and absolute amounts of lean body mass and depot fat were calculated using a conversion formula (Brožek, 1954).

The estimation of body composition from body density (Rathbun et Pace, 1945) has been used by a number of authors for different purposes including the study of sexual differences in adults, changes due to ageing, overnutrition or undernutrition and influence of physical activity (Behnke et al., 1942; Brožek et Keys, 1951; Brožek, 1952; Keys et Brožek, 1953; Brožek et al., 1953; Behnke et al., 1953; Khanina et Chagowetz, 1954; Behnke et al., 1956; von Döbeln, 1956; Drobný, 1958; Pařízková et al., 1960; Zhdanova, 1962a, b; Fomon et al., 1963; Pařízková et Eiselt, 1966; Durnin et Rahaman, 1967). A comprehensive survey on the results was provided at the Conference on Body Composition held at the New York Academy of Sciences in 1963 (Annals of the New York Academy of Sciences 1963, vol. 110). — Densitometry, involving hydrostatic weighing is technically relatively simple. However the essential assumption basic to calculations of body composition from body density, i.e., that the density of both lean body mass and depot fat is constant (Brožek et al., 1963) has not been directly verified in human subjects especially during growth. But Moulton (1926), proved that in all organisms there exists a certain stage of development (in man approximately four years) after which under physiological conditions no substantial changes in the proportions of main chemical components occur in fat-free body mass.

What further complicates the calculations of body composition from body density are possible changes in total, resp. in extracellular water, and changes in skeleton robusticity and mineralization. As regards the first point, under normal physiological conditions, controlled in the present study by thorough clinical examinations, no substantial changes in the relative amounts of body water can be expected. As regards the latter point, we checked two indicators — the breadth of the wrist and femoral condyles together with the roentgenographs of the hand.

During last years the measurement of K^{40} by means of whole-body counters were used for estimation of lean body mass and its changes during growth and development (Anderson et Langham, 1959; Allen et al., 1960; Forbes, 1962; von Döbeln, 1962; Kirton et Pearson, 1963; Forbes et Hursh, 1963). There is a rather good agreement between the results concerning the trends of changes in body composition obtained by this method and body density measurements (Pařízková, 1959; 1961b, 1963b; Novak, 1963; 1966). According to Hampton et al. (1966) there is a close relationship between the results of these two methods especially in boys (correlation coefficient r = 0.88). A longitudinal growth study by means of K^{40} measurement has not been reported yet. But it is theoretically possible that K^{40} proportions in various tissues (von Döbeln, 1962) could change during growth and development comparatively more than their densities; this ought to be verified yet.

Thicknes of the skinfolds was measured by means of a caliper designed after Best (1954) and modified according to our needs (Čapková—Pařízková, 1957, Pařízková, 1960b; 1962). This caliper has circular contact surfaces 3 mm in diameter. Total pressure is 200 g. It was chosen according to its simplicity and easy control of the stability of the pressure on measured skinfold in all ranges. The data ascertained by this caliper can be compared with those gained by other calipers, e.g. the Harpenden caliper (Tanner et Whitehouse, 1955) using regression equations and nomographs (Pařízková et Goldstein, 1970). The coefficient of variation of repeated measurements made by our caliper is on the average 6.4 for individual skinfolds, and 2.0 for the sum of ten skinfolds. From the skinfolds the total body fat can be estimated for children and adolescents, by means of nomographs and regression equations (Pařízková, 1961b; 1962), as for adults (of e.g. Allen et al., 1956; Pařízková et al. 1960; Pařízková et Eiselt 1962). Skinfolds were measured on the cheek, under the chin, on the thorax at the anterior axillary line, on the arm above the triceps, on the back below the scapula (subscapular), on the thorax above the tenth rib in the prolongation of the anterior axillary line, on the abdomen (at the line navel — spina ilica anterior, nearer to the navel), on the hip above the iliac crest in the prolongation of the anterior axillary line (suprailiac skinfold), on the thigh above the patella and on the calf bellow fossa poplitea. These sites were chosen according to Allen et al. (1956) and slightly modified on the basis of our experiences in measuring children (Čapková—Pařízková, 1957; Pařízková—Čapková, 1959; Pařízková, 1960, 1961, 1962). All measurements were made on the right side.

Altogether 61 morphological characteristics were assessed including anthropometric dimensions in absolute values, then relative dimensions characterising body build, lean body mass and depot fat both in absolute and relative values, and finally skinfold thicknesses, single and summated.

Skeletal age was ascertained from roentgenographs of the hand according to Greulich and Pyle (1956), Johnston (1964), Johnston and Jahina (1965).

The choice of anthropometric characteristics (length of the extremities, circumferential measures of the thorax and the extremities) was motivated in part by considerations of possible changes due to different physical activities.

Statistical treatment of the data utilized standard statistical methods. Mean values ($\bar{x}$) and standard errors of estimate (SE) of the basic measurements and of yearly increases were calculated. Statistical significance of the differences was evaluated by means of Student's T-test. For selected characteristics (lean body mass) the analysis of covariance was used for testing possible differences among groups adapted to body height (Fischer, 1948; Weber, 1957).

Selected linear data were correlated for pooled subjects and years (Mordekai and Fox, 1965). Statistical significance of correlation coefficients is indicated for $p < 0.05$ and 0.01. In selected cases linear regressions and s were calculated in addition.

IV. THE DEVELOPMENT OF HEIGHT, WEIGHT AND CHEST CIRCUMFERENCE

In a comprehensive monograph Tanner (1962) surveyed available data on child growth. One of the striking findings is the acceleration of growth in height and weight in comparison with the past century. Same trends were described for the Soviet Union by Tarasov (1958) and Vlastovskij (1963). Increases in adult height and weight were observed in many countries too (Heimendinger, 1958; Tonelli, 1959; Prokopec, 1956; 1961; Wolański, 1956; Fetter et al., 1963), what is obviously connected with accelerated child growth and development who much sooner reach higher values of various anthropometric dimensions (Hrdlička, 1920; 1936; Matiegka, 1923) and sooner sexual maturation (Grimm, 1958).

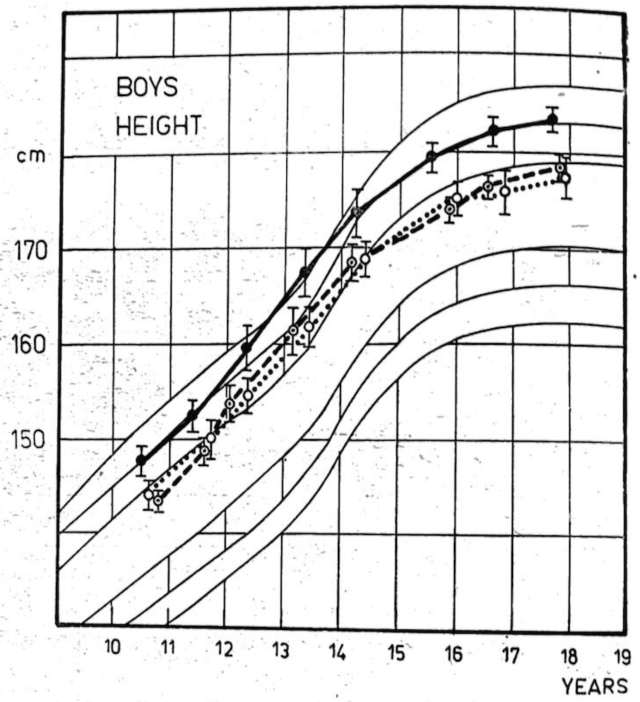
Greater dimensions of the human body are generally regarded as positive and a result of improved conditions of life, including better nutrition and hygiene of children as well as of mothers. However increased size of the organism does not always mean also a better functional qualities (Pařízková, 1967b, 1968a, c, g).

Longitudinal studies of growth were made in various countries including USA (Stuart et al., 1940; Stuart et Reed, 1951, Falkner, 1964 etc.), England (Tanner, 1964c), France (Sempé et al., 1964), Belgium (Simonart-Courbier, 1963; Adiel, 1964) and Sweden (Karlberg, 1964). At present these studies are coordinated by the Centre International de l'Enfance in Paris.

The influence of exercise on somatic growth has been studied to a limited extent. Some authors (e.g. Schwartz et al. (1928), Arnold (1930), Correnti (1950) described increased rate of growth due to physical exercise but Tanner (1962) felt that define conclusions would be premature. Matching of the exercised and control groups is essential but difficult, and sufficiently long periods of investigation are needed.

Mean values of height and weight measured during the eight years of our study were compared with various norms for children of the same age. We used Czech standards (Kapalín et al., 1957) as well as standards developed for American children (Wetzel, 1942). These comparisons showed no significant differences, i.e. our boys represented physically an average of boys' population in this age period.

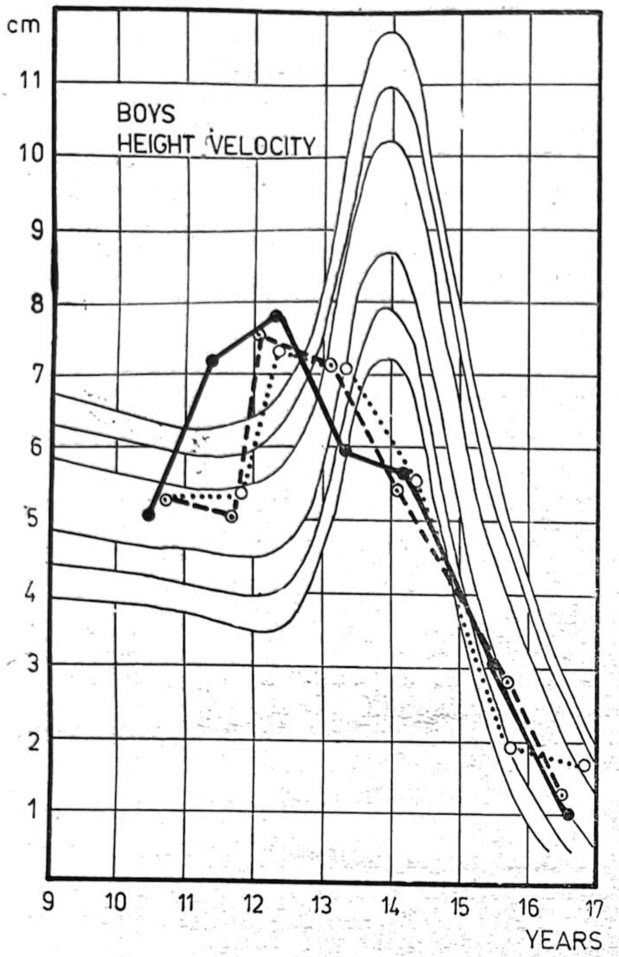
Further we compared the development of our subjects with standards for British boys provided by Tanner et al. (1966) on basis of longitudinal measurements. In Figure 1 the mean values of height and their changes are presented against the background of Tanner's standards. The height increases did not differ significantly from average English population.



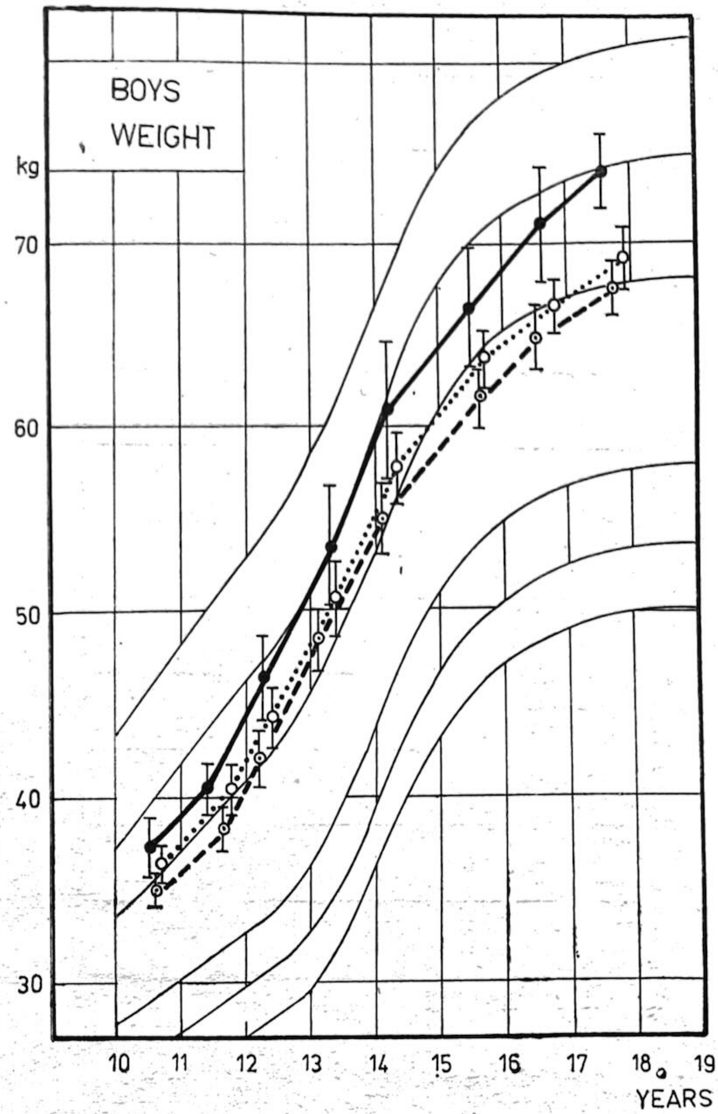
1. Development of height in boys of different physical activity (group I —●—●—, group II — —⊙— —⊙—, group III ....O....O....O) from 10.6 to 17.17 years of mean age on the background of height standards of Tanner et al. (1966).

Differences were present between our subgroups, *viz.*, between group I and III and I and II in all investigated years: boys of group I were tallest during the whole experimental period. Relative change (expressed as percent increase of initial value ascertained in the first year of our investigation, equalling thus 100 %) is given on the right side of the curves (+%). This relative change was very approximately the same in all three groups, i.e. about 23.8—24.3 %.

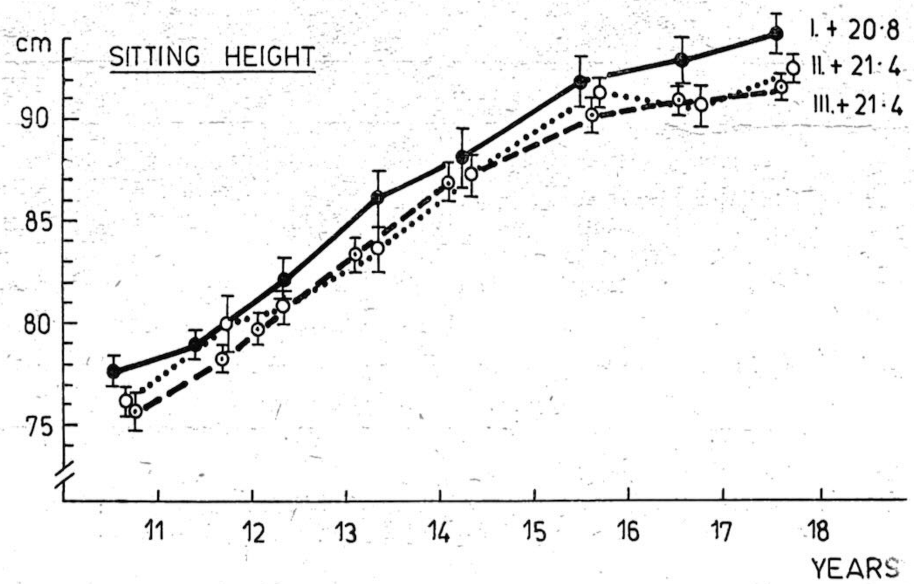
Figure 2 presents height increments in reference to Tanner's height velocity standards. Increases



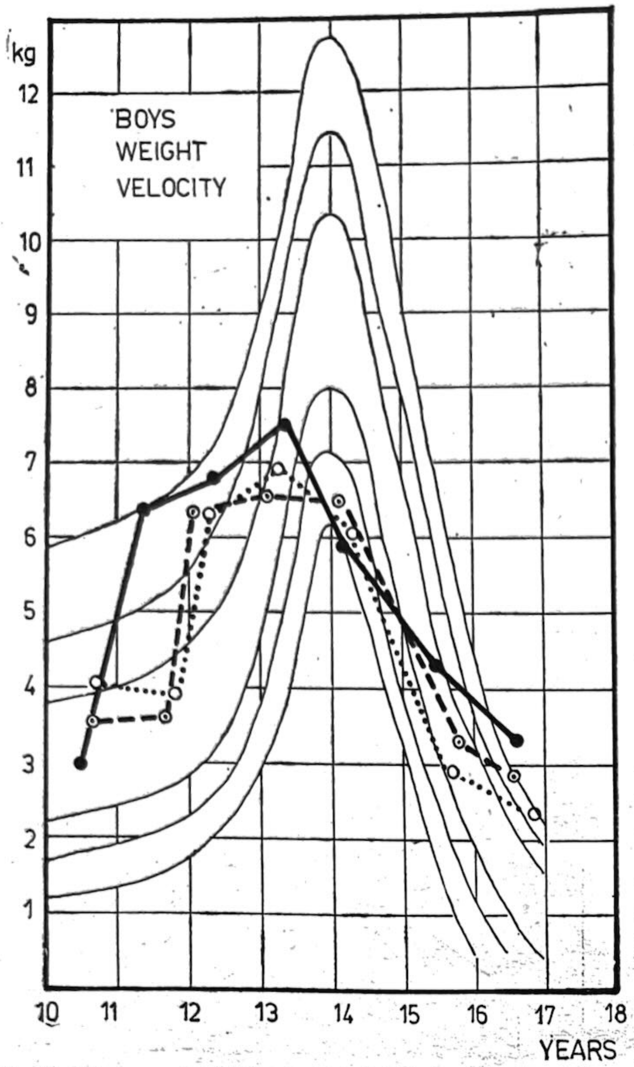
2. Development of height velocity (cm/year) in boys of different physical activity (groups I—III) from 10.6 to 17.7 years of mean age on the background of height velocity standards of Tanner et al. (1966).



4. Development of weight in boys of different physical activity (groups I—III) from 10.6—17.7 years of mean age on the background of weight standards of Tanner et al. (1966).



3. Development of sitting height in boys of different physical activity (groups I—III) from 10.6—17.7 years. Numbers on the right side of the curves indicate + percent increase during longitudinal study (expressed in the relationship to the values ascertained in the first year of investigation = 100 %).



5. Development of weight velocity (kg/year) in boys of different physical activity from 10.6 to 17.7 years of mean age of the background of weight velocity standards of Tanner et al. (1966).

were higher in group I especially in the second year.

Since we wanted to know whether the growth of the trunk followed the trend of total height we measured sitting height. Figure 3 shows that there were significant differences between group I and II in the 2nd, 3rd, 4th, 6th, 7th, 8th years, and between group I and III in the 2nd, 4th, 7th and 8th years. The relative change was the same, i.e. about 20.8—21.4 %.

Figure 4 illustrated body weight changes plotted against Tanner's standards. There were no differences in body weight in the first year between groups differing extremely in physical activity, i.e. I and III. This difference appeared in the 7th and 8th year of our study only. Mean weight in group II was always lowest during the whole investigation period. Relatively the body weight nearly doubled (increased about 89.6—98.5 %) during eight years of our study. Weight increases are given separately in Fig. 5.

On the basis of the data presented above we can conclude that boys of group I who were mostly interested and systematically involved in regular physical exercise in all eight years were always significantly tallest. Body weight however was significantly higher in group I than in group III in the 7th and 8th year only. Lowest weight and height had boys of group II.

V. THE DEVELOPMENT OF SKELETAL AGE

The roentgenographs of the hand were taken in standard position and evaluated according to Greulich et Pyle (1959). The results are presented in Table 1. The comparison of mean values for the first year showed no significant dif-

TAB. 1

The development of chronological and skeletal age in boys ($n = 41$) during eight years

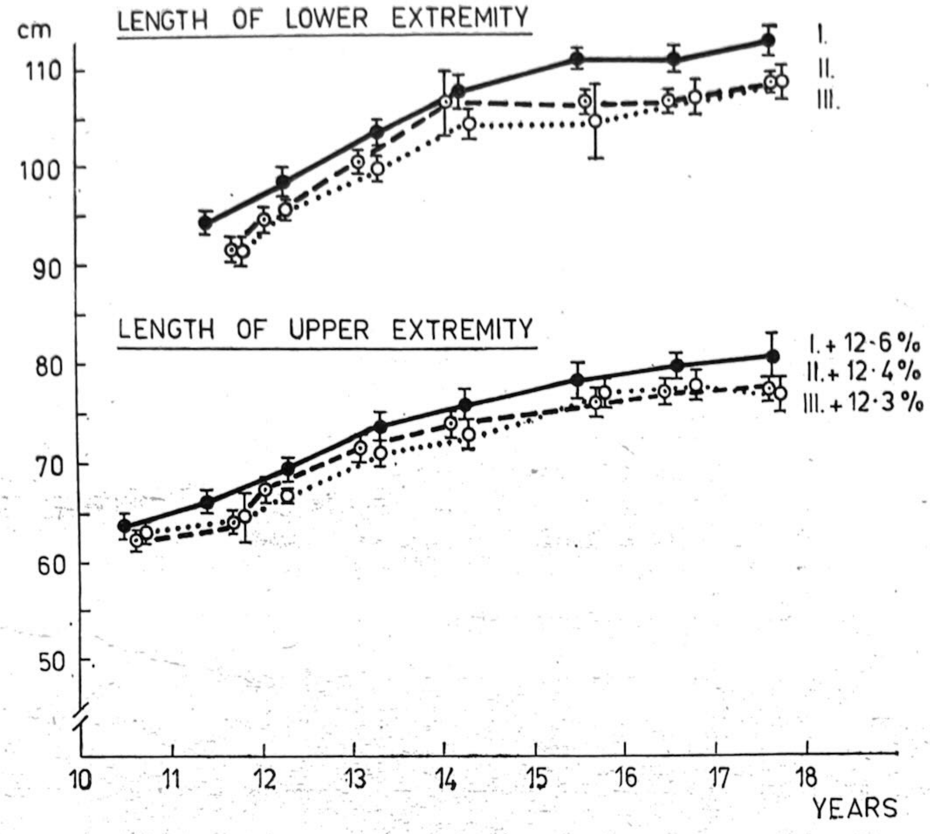
Years	1 1961	2 1962	3 1963	4 1964	5 1965	6 1966	7 1967	8 1968
Chronological age								
I. $\bar{x}$	10.34	11.43	12.35	13.37	14.26	15.58	16.60	17.68
I. *SE*	0.13	0.16	0.16	0.16	0.12	0.15	0.15	0.12
II. $\bar{x}$	10.72	11.74	12.05	13.11	14.13	15.72	16.50	17.72
II. *SE*	0.14	0.09	0.05	0.07	0.07	0.07	0.21	0.07
III. $\bar{x}$	10.70	11.80	12.38	13.38	14.30	15.71	16.80	17.78
III. *SE*	0.16	0.14	0.14	0.14	0.13	0.12	0.10	0.12
Skeletal age								
I. $\bar{x}$	10.85	11.70	12.70	13.77	15.04	16.10	17.17	18.06
I. *SE*	0.15	0.08	0.08	0.11	0.13	0.17	0.14	0.13
II. $\bar{x}$	10.86	11.86	12.81	13.70	14.57	15.76	17.06	18.09
II. SE	0.83	0.90	0.60	0.89	1.26	2.58	2.42	1.87
III. $\bar{x}$	10.38	11.60	12.55	13.41	14.27	15.53	16.94	18.05
III. *SE*	1.22	1.17	1.16	0.82	1.20	1.56	1.04	1.00

ferences: the stage of skeletal maturation at the beginning of our study was comparable for all groups. During subsequent years the skeletal maturation developed in the same manner in all groups and was not influenced by physical activity.

When we compared skeletal age with chronological age we see that in most instances the skeletal age in groups I—II was a little more advanced than the chronological age (significantly in group II in the 3rd and 4th year only).

fig. 6), and of segments acromion — radiale, and radiale — stylion (Tab. 2). Most often significant differences in total length of the upper extremity between group I and II were ascertained; between group I and III only in the 6th and 8th years of our study. Mean values of relative increases amounted to 23.2—26.6 % from the first to the eighth year.

Acromion — radiale and radiale — stylion developed in the same manner; the increases were harmonious in all years. Only one significant dif-



6. Development of total length of the upper extremity (acromion—radiale) and lower extremity (cristale—base) in boys of different physical activity (groups I—III) from 10.6 to 17.7 years of mean age. Numbers on the right side of the curves indicate + percent increase during longitudinal study (values in the first year = 100 %).

From the point of view of skeletal maturation our groups were fairly homogenous and comparable not only at the beginning (in spite of significantly greater values of body height in group I) but also at the end of our investigation. The intensity of physical exercise in described range had no influence on skeletal maturation.

VI. THE DEVELOPMENT OF THE LENGTH DIMENSIONS OF THE EXTREMITIES

Change in the growth rate of upper and lower extremities, in relation to adult values were reported by Simmons (1944). These data too are reviewed in Tanner's monograph (1962).

On the upper extremity we measured three dimensions — total length (acromion — dactylion, ference was ascertained, i.e. between group I and III in the distance radiale — stylion in the 8th year; therefore mean values for all groups together are given in Table 2. The relative changes of these dimensions represented 25.9 % in acromion — radiale, and 20.9 % in radiale — stylion (Tab. 2).

Figure 6 shows the development of the lower extremity as total length. Unfortunately we had no opportunity to measure the total length of the lower extremity in the first year of our investigation, so only mean values in group I—III from the 2nd to the 8th year are available. Since the second year there is a significant difference between group I and II and I and III till the last year. In the group I the dimension iliospinale — tibiale (Tab. 3) was also significantly longer in comparison with group II and III. Mean values of relative increases of this dimension in the last year amounted to 26.9—28.3 % from the first to the eighth year.

Tibiale — sphyrion (Tab. 3) developed very similarly as aforementioned dimension, a significant difference between group I and III only in the 6th year was proved. The relative change represented +20.1—23.4 % of initial value.

Comparison of relative changes both of upper and of lower extremities revealed that the proximal segments (acromion — radiale and iliospinale — tibiale) increased in the experimental period a little more than the distal segments (radiale — stylion and tibiale — sphyrion).

VII. DEVELOPMENT OF THE CIRCUMFERENCES OF THE EXTREMITIES

On the upper extremity the circumference above the biceps was measured on the left and right side during muscle contraction and relaxation. As there were no significant differences between the circumferences of the two sides only the mean values for the right side are presented in Table 4.

In the first year of our investigation there were no differences in mean values of arm circumferences in contraction or in relaxation. The development of this dimension in the subsequent years was identical in all the groups and even in the last year there were no significant differences between groups I—III. Greatest change occurred from the 4th to the 5th and from the 6th to the 7th years. The mean values in the last year were larger by +28.8—40.9 % than in the first year.

The circumference of the forarm was identical in the first year in all groups (Tab. 4). Mean values slightly decreased from 11 to 12 years, and then increased nearly linearly until the last year. As in length dimensions, the relative developmental chan-

TAB. 2

The development of mean values of acromion — radiale and radiale — stylion dimensions in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968	+%
Acromion — radiale									
$\bar{X}$	26.2	26.9	28.6	30.1	30.9	32.5	32.8	33.0	+25.9
SE	0.3	0.2	0.2	0.2	0.2	0.2	1.1	0.4	
Radiale — stylion									
$\bar{X}$	21.5	21.9	23.0	23.9	24.9	25.6	25.7	26.0	+20.9
SE	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.3	

TAB. 3

The development of mean values of the distance iliospinale — tibiale and tibiale — sphyrion in groups I.—III. during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968	+%
Iliospinale — tibiale									
$\bar{X}$	43.6	44.9	46.8	46.9	52.1	53.8	55.0	55.3	+26.9
I. *SE*	0.7	0.7	0.6	0.4	1.2	0.7	0.7	0.8	
$\bar{X}$	42.6	44.1	44.8	45.0	51.8	52.5	53.6	53.6	+25.7
II. *SE*	0.5	0.5	2.3	0.7	1.6	0.4	0.5	0.5	
$\bar{X}$	41.6	43.5	44.7	44.8	50.4	51.7	53.1	53.4	+28.3
III. *SE*	1.9	0.6	0.6	1.0	1.0	1.2	0.9	1.5	
Tibiale — sphyrion									
$\bar{X}$	34.3	35.7	38.0	40.0	41.0	42.0	42.1	42.3	+23.4
I. *SE*	0.9	0.6	0.5	0.6	0.7	0.5	0.3	0.5	
$\bar{X}$	33.4	34.2	36.3	38.6	40.0	40.0	40.5	40.9	+22.2
II. *SE*	0.5	0.4	0.4	0.6	0.4	0.3	0.3	0.3	
$\bar{X}$	34.1	34.9	36.9	38.5	39.6	39.8	40.8	40.9	+20.1
III. *SE*	0.8	0.7	0.5	0.5	0.7	1.2	0.8	1.0	

TAB. 4

The development of the circumferences of the extremities in boys ($n = 41$) during eight years

Years		1961	1962	1963	1964	1965	1966	1967	1968	+%
Arm rel.	$\bar{X}$	22.0	21.1	21.4	23.3	25.0	25.8	27.1	28.3	+28.8
	SE	1.2	0.3	0.3	0.3	0.4	0.4	0.3	0.3	
Arm contr.	$\bar{X}$	21.8	23.0	24.2	25.3	27.3	28.2	29.4	30.8	+40.9
	SE	0.5	0.3	0.3	0.3	0.4	0.4	0.3	0.3	
Forarm	$\bar{X}$	21.6	21.3	22.3	23.4	24.6	25.5	26.2	26.9	+24.3
	SE	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	
Thigh	$\bar{X}$	43.1	44.1	46.2	47.9	50.3	51.3	53.4	54.7	+26.9
	SE	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	
Calf	$\bar{X}$	29.2	30.3	31.5	32.7	34.4	35.6	37.1	37.6	+28.6
	SE	0.2	0.3	0.3	0.3	0.3	0.3	0.6	0.6	

ges of the forarm as a more distal segment are relatively smaller than those of the more proximal (arm), with mean incremental values being +24.3 per cent (Tab. 4).

On the lower extremity the circumferences of the thigh and the calf were also measured bilaterally. Comparing mean values of both sides we found slightly lower values on the left side but the differences were far from having statistical significance. For this reason only mean values of the right side are presented here.

Thigh circumference (Tab. 4) was the same in the first year in all the groups and this did not change till the fifth year. From the first to the last year the development was nearly linear. Total increments were +26.9 %.

Calf circumference increased at the same rate in all groups during the eight years. Significant differences were found neither in the first nor in the last year of our investigation. Final increments were +28.6 %. In comparison with relative changes of the circumference of the thigh this increase was nearly the same (Tab. 4).

The influence of increased physical activity on the development of circumferential dimensions was not established even though in this case it might be expected. It is known that increases in arm circumference due to muscle hypertrophy are often found in trained subjects in comparison with untrained ones. The absence of this phenomenon in our boys could be explained in part by the fact that even if some muscle hypertrophy would have occurred in boys with increased physical activity it could be compensated by decreased layer of subcutaneous fat. This was verified by analyses of lean body mass proportion and fat measurements.

VIII. DEVELOPMENT OF THE CHEST

In table 5 the development of the shoulder breadth (biacromial diameter) is illustrated. Initial values were identical for all groups. No change occurred from the first to the second year, but afterwards mean values increased continually till the last year. Maximal increase was found again in the period from the 4th to the 5th year; in the last year this dimension increased +26.3—30.7 % of initial value. There was no significant difference among the groups in the first year, but since third year mean value in group I was significantly higher than in group II and III.

In table 5 also mean values for chest breadth are given. This dimension is the same for all groups investigated both at the beginning and at the end. Until second year mean values increased only slightly; then the chest breadth increased somewhat from the 2nd to the 4th year. But the greatest change occurred from the 4th to the 5th year again. Relative total change represented +30.5 % of initial value.

Chest depth had a very similar trend of development — stagnation during the first year and then a mild increase during the subsequent years. During last year the increase in chest depth was relatively smaller than for chest breadth. The total relative change represented +31.0 % of initial value. There were no differences according to physical activity.

In addition the circumferential measures of the chest were taken as well (Tab. 6). Chest circumference at rest was identical in the first year, in the last year the mean value was significantly highest in group I in comparison with group II and III. Mean values were lowest in group II since second year. Chest circumference at rest increased by +31.6—37.3 % of initial value.

The development of the chest circumference at inspiration and expiration has been similar as in abovementioned characteristic — slowest at the beginning and most intensive during last year.

Significantly highest mean values in group I were found in both cases. Relative change for inspiration was +31.5—34.2 %, for expiration 30.9—35.4 % of the initial value.

J e u r i s s e n (1959) assumed on the basis of his measurements by means of roentgenography that the upper part of the thorax and the apices of the lungs grow relatively more than the remainder in the adolescents. — The respiration range, i.e. difference between the circumference at inspiration and expiration has been increasing during the whole period studied in the same manner in all groups. Relative increase of this characteristic is +29.9 %.

IX. DEVELOPMENT OF THE PELVIS

Two pelvic dimensions were measured: bicristal diameter (upper part growth) and bitrochanteric diameter (lower part growth).

The developmental trends of these two dimensions were not identical. Bitrochanteric diameter changed only slightly from the first to the second year of age. Then it increased steadily till the 6th year (Table 5). Relative change during the investigation period represented +31.8 % of initial value.

Simmons (1944) found in his mixed semi-longitudinal study slightly higher increases in absolute values of bitrochanteric width from 11 to 12 years, slightly lower increases from 12 to 14 years and markedly lower increases from 14 till 15 years. Greatest difference between his and our data are in the rate of changes from 14 to 15 years.

Second dimension on the pelvis, the bicristal diameter increased only from the first to the second and then from the 4th to the 7th year. Maximal change occurred from the 4th to the 5th year, as given in Table 5. Between the 2nd and the 4th year the increases were negligible both from absolute and from relative point of view (Table 5). The mean values in the last year were larger by 39.9 % than in the first year.

The influence of increased physical activity was not manifested significantly in the development of both pelvic dimensions.

X. DEVELOPMENT OF BODY COMPOSITION

One of the most often used methods for the characterization of body composition is roentgenography and skinfold measurements. There is a good agreement between the results of these two methods (Hammond, 1955; Garn et Gorman, 1956; Tanner et Whitehouse, 1962; Tanner,

TAB. 5

The development of breadth measures in boys of different physical activity during eight years

Years		1961		1962		1963		1964		1965		1966		1967		1968		+%
		$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	
Biacromial breadth (cm)	I	30.9	0.9	31.3	0.7	33.5	0.7	36.6	0.8	37.6	1.1	39.3	0.8	39.7	0.7	40.4	0.4	30.7
	II	31.1	0.4	10.7	0.4	33.0	0.4	34.9	0.3	36.8	0.4	38.0	0.6	38.7	0.3	39.3	0.3	26.3
	III	30.7	0.3	30.7	0.5	32.6	0.4	34.6	0.4	35.9	0.6	38.4	0.3	38.6	0.4	39.1	0.4	27.3
Chest breadth (cm)		21.6	0.2	21.6	0.2	22.5	0.2	23.0	0.3	26.3	0.3	28.3	0.3	28.3	0.4	28.2	0.3	30.5
Bicristal breadth (cm)		19.8	0.2	21.8	0.2	22.1	0.2	22.5	0.3	26.4	0.3	27.4	0.3	27.6	0.2	27.7	0.2	39.9
Bitrochant. breadth (cm)		24.5	0.2	24.8	0.3	26.9	0.3	28.4	0.4	30.7	0.4	31.8	0.3	32.3	0.3	32.3	0.2	31.8
Wrist breadth (cm)		4.7	0.1	4.8	0.1	4.9	0.1	5.3	0.1	5.3	0.1	5.6	0.1	5.6	0.1	5.8	0.1	23.4
Femoral condyles (cm) breadth		9.1	0.1	9.1	0.1	9.2	0.1	9.6	0.1	9.6	0.1	9.7	0.1	9.7	0.1	9.9	0.1	8.8

TAB. 6

The development of mean values of chest circumferences (rest, inspirium, expirium) in boys during eight years

Years		1961	1962	1963	1964	1965	1966	1967	1968	+%
Chest circ. (rest)	I. $\bar{X}$	69.5	72.1	75.0	78.6	84.1	87.8	91.6	95.5	+37.3
	I. SE	1.1	1.2	1.3	1.6	1.9	1.5	1.6	1.5	
	II. $\bar{X}$	68.2	69.0	71.5	75.5	80.4	84.9	88.0	90.5	+32.6
	II. SE	0.6	0.6	0.9	1.1	1.3	1.3	1.0	0.9	
	III. $\bar{X}$	69.2	71.5	74.0	77.9	82.6	86.9	89.7	91.1	+31.6
	III. SE	1.1	1.4	1.4	1.5	1.5	1.3	1.2	1.4	

1962). Data concerning skinfold thickness measurements during growth (Franzen, 1929; Kornfeld et Schüller, 1930; Meredith, 1935; Correnti, 1950) are abundant enough but, unfortunately, the methods (pressure, shape and size of contact surfaces of the calipers, choice of the skinfolds and their localization, presentation of the data) are so different, that it is difficult to compare the results.

In children the development of subcutaneous fat by means of calipers was measured by Batkin (1915), Lauter et Terheddebrügge (1938; quot. Keys et Brožek, 1953) and many others. Description of subcutaneous fat and muscle development by means of roentgenography was given by Stuart et Sobel (1946), Garn et al. (1956), Tanner (1962), Johnston et Malina (1966), Malina (1966).

Systematic research on body composition, i.e. measurement of lean body mass and depot fat in the organism of children was started in cross-sectional studies long ago already. However there are difficulties in comparing results from methodological reasons too: Boyd (1933), e.g. ascertained specific gravity of children by voluminometry but without simultaneous measurements of the volume of the air in the lungs and respiratory passages, and so these data can be considered as approximative only. The same applies to Zook's data (1938). Zook constructed an apparatus for the measurement of the whole body volume and of its parts (head, trunk, extremities). It is not possible from these data and the data of some other authors (e.g. Mumford, 1927) to calculate the proportions of lean body mass and depot fat. By contrast Behnke and his collaborators (1942) ascertained following hydrostatic weighing, the volume of residual air. This method however has been used for a long time for adults only (Keys et al., 1950; Keys et Brožek, 1953; Brožek, 1952; Brožek et al., 1963; Young et Martin, 1961; Pařízková, 1959, 1960, 1961 etc.). Sexual differences, influence of nutrition etc. were described using this approach.

Our first measurements concerned skinfold thickness development during ontogeny (Čapková—Pařízková, 1957; Pařízková—Čapková, 1959) starting from several hours after birth (Pařízková, 1963) throughout childhood and adolescence to senescence (Pařízková, 1960; 1962; 1963a; Pařízková et Eiselt, 1966, 1968). All measurements were made by the same method under the same conditions. Only healthy subjects were included in investigated groups.

Proportion of lean body mass and depot fat by means of densitometry, with simultaneous measurement of the air in the lungs and respiratory passages as described by Brožek et al. (1949), were measured first in Czech children sytematically from seven years of age (Pařízková, 1959; 1960; 1961a, b) to eighteen years. Novak (1963) used the same method for studies on American adolescents, together with creatinine excretion. There was a good agreement between mean values of body density of American and Czech boys, but as regards the girls the body density was lower in the Czech girls (Pařízková, 1959; 1961; 1962; 1963b; Novak, 1963). Hunt et Heald (1963) studied hydration of lean body mass and mineralization of the bones in the early stage of sexual maturation; they showed stabilization of these values at the age of 16 years.

The influence of physical activity on body composition in adults in many cross-sectional studies was followed (Behnke et al., 1942; Khanina et Chagowetz, 1954; Drobny, 1956; Pařízková, 1959; 1962). In children (Pařízková, 1959; 1962) and older people (Pařízková et Eiselt, 1966; 1968) the same changes in body composition were proved, i.e. the increase in lean body mass at the expense of fat (Pařízková, 1968; 1966c). In girls a longitudinal study from 13 to 18 years was carried out; changes of height, weight and of skinfold thickness were ascertained (Pařízková—Čapková, 1959; 1963b; 1965; Pařízková et Poupa, 1963).

Changes in total body fat and skinfold thickness in obese children due to increased physical activity were studied longitudinally during various phases of reducing therapy (Pařízková et Vamberová, 1961; Pařízková et al., 1962, 1965). Densitometric analysis revealed marked quantitative differences in the proportions of fat and lean body mass even in the cases when changes in total body weight were not remarkable; reduction of fat was accompanied by increase of lean body mass (Pařízková et Vamberová 1961, 1967).

A longitudinal study of body composition, body conformation and their association with nutrition and activity in American teen-age population from 14 to 17 years was undertaken by Huenemann et al. (1966). A number of anthropometric dimensions was studied together with food and physical activity habits by means questionnaires. The proportion of lean body mass and fat was calculated from anthropometric dimensions according to Behnke (1961). In selected subjects the results were compared with densitometric estimates (hydrostatic weighing) and K^{40} measurements by means of whole-body counters. Good agreement between densitometry and K^{40} measurements especially for boys was demonstrated. The correspondence between anthropometric estimation of body composition and the other two methods was poorer (Hampton et al., 1966). The aim of the study was to investigate teen-agers view on their body size and shape, their eating habits and practises, and their interest in modifying any of these. The study evaluated questionnaire responses by sex, three racial groups, and body fat classifications based on anthropometric determinations made repeatedly from 14 to 17 years (Huenemann et al., 1966).

We did not find any data on longitudinal body composition measurements in this period of age, considered with reference to physical activity. — In regard to body density it was not possible to exclude the possible effect of differences in robusticity of the skeleton. But von Döbeln (1959) found highly significant positive correlation between body height, breadth of the wrist and femoral condyles on the side and the amount of lean body mass on the other side.

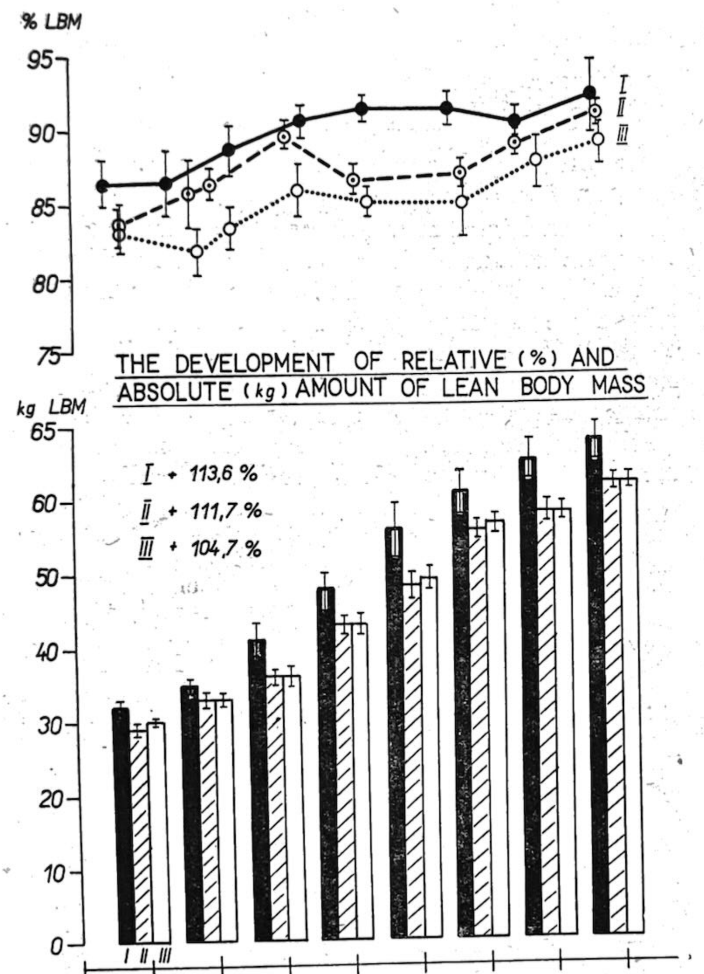
For characterizing robusticity of the skeleton and its changes during growth and development we measured breadths of the wrist and femoral condyles. There were differences according to physical activity; the results are given in table 5. During the experimental period only small changes occur in both measurements: the breadth of the femoral condyles increased only by 8.8 % of initial value. The breadth of the wrist changed more. The total increase represented +23.4 % of initial value.

Nor were there differences in the maturation and mineralization of the bones of the wrist, as was demonstrated in table 1; we concluded that changes in body density are due primarily to various proportions of lean body mass and depot fat.

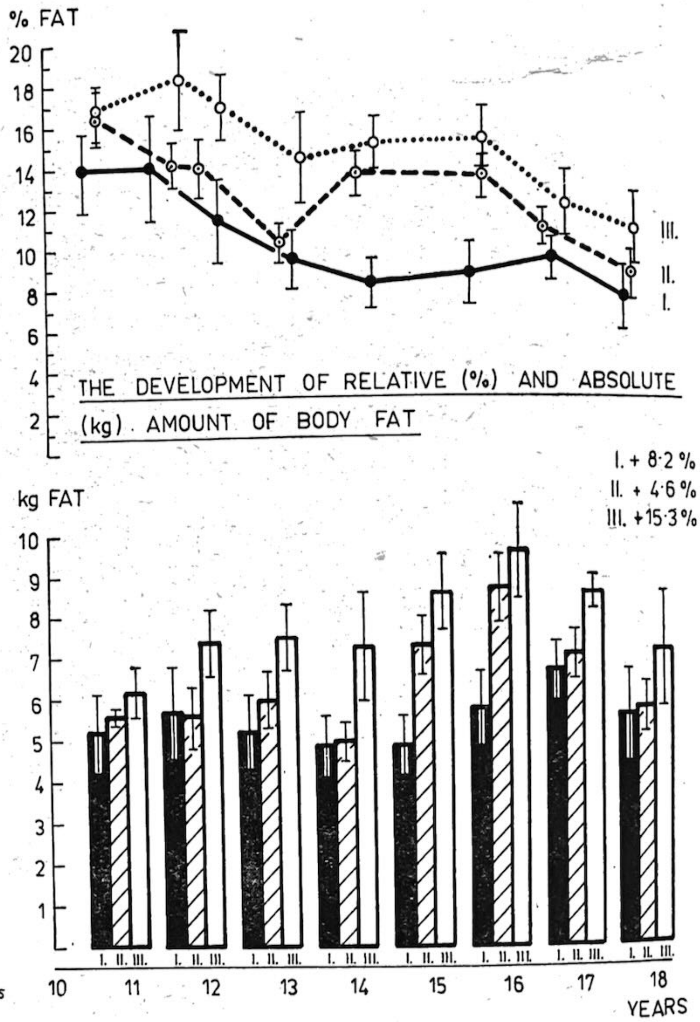
In figure 7. we can see the development of absolute and relative amounts of lean body mass. In the first year there were no significant differences among the groups as regards the relative or the absolute amount of lean body mass. In the second year there were significant differences in the proportion of lean body mass between groups I and III. This was caused by a slight decrease of the relative amount of lean body mass in boys of group III. In the third year the relative amount of lean body mass increased in all groups (acceleration of growth), significantly most in group I. In the fourth year there was a significant difference between group I and III and group II and III. In the 5th and 6th year the differences according to physical activity were mostly marked (Pařízková 1968 e, f) and significant between group I and II and I and III. In last two years there were significant differences between group I and III, but at that time these differences were less marked than in preceding years.

The same was found for the absolute amount of lean body mass (kg). There were no differences in the first and second years of our investigation. Later on the amount of lean body mass increased most in group I (fig. 7). The differences between the groups reached significance for group I and II, and I and

Fig.8.



7. Development of lean body mass in relative and absolute amounts in boys of different physical activity (groups I—III) from 10.6 to 17.7 years.



8. Development of body fat in relative and absolute amounts in boys of different physical activity (groups I—III) from 10.6 to 17.7 years.

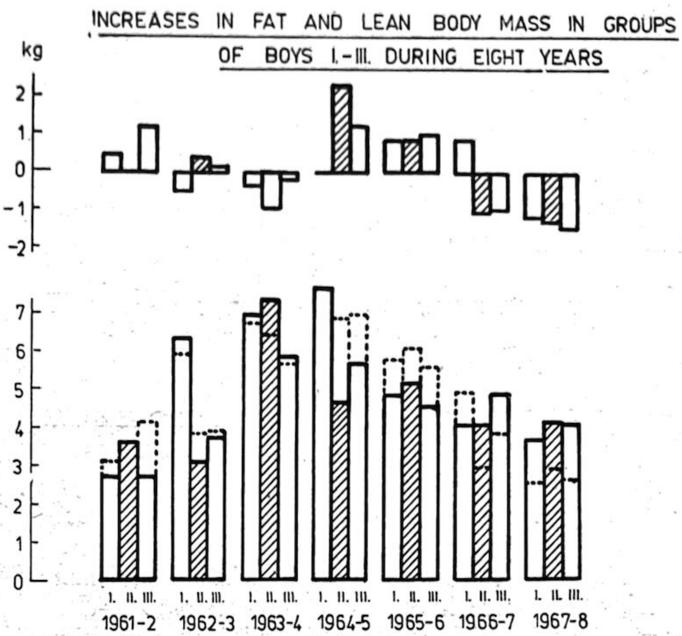
III starting with the third year of our investigation.

According to significantly higher values of body height in boys of group I starting with the first years of our study a possible relationship between body height and lean body mass was considered. Analysis of covariance showed that these indicators were not at all related in the first year (1961 — $F =$ 0.162). The same applies for the development of body height and lean body mass in the following years, when these indicators were not significantly related as well (1965 — $F = 2.666$; 1968 — $F =$ 3.091; d.f.: $F_1 = 1$, $F_2 = 36$).

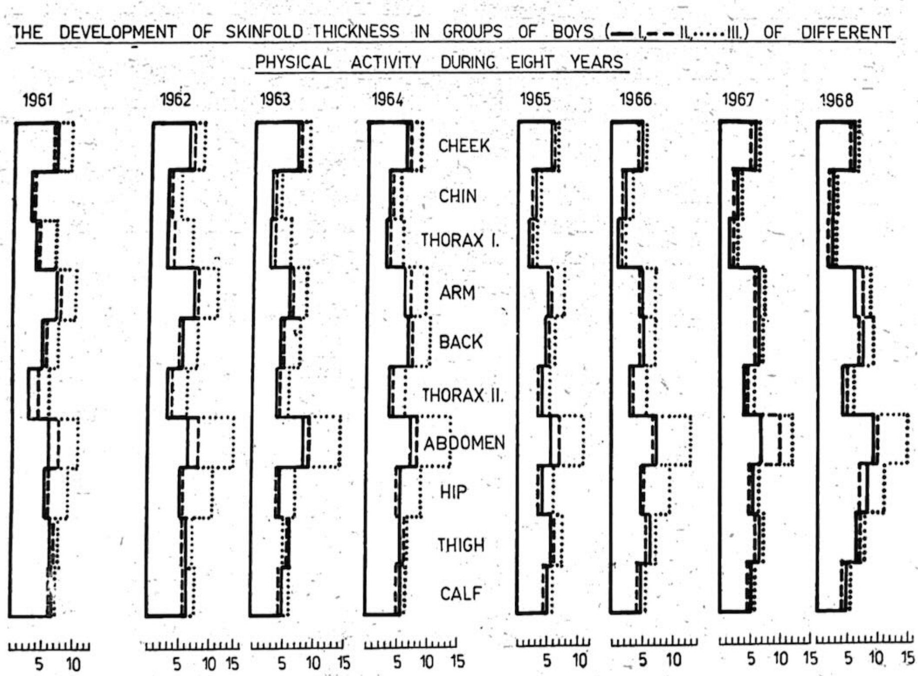
Figure 8. illustrates the development of body fat in relative and absolute values. In the first year there were no significant differences among groups. In group I the proportion of body fat was decreasing significantly more until 5th — 8th year of our study than in group III. The differences between groups became significant in the second year. The absolute amount of depot fat was also the same in all groups at the time of the first measurement in 1961. Later it increased significantly more in group III, and remained the same in group I (fig. 8).

Developmental trend of relative and absolute changes in lean body mass and depot fat is in agreement with the results of our previous cross-sectional studies (P a ř í z k o v á 1959, 1961, 1962, 1963 b), as well as with the results of other authors (N o v a k, 1963, 1966; T a n n e r, 1962; B r o ž e k, 1966 etc.).

Figure 9. illustrates separately the increments (respective losses) of depot fat and lean body mass in the course of the whole period of our investigation 1961 — 1968, and indicates in greater detail the changes in individual years and individual groups. Interrupted line in the columns (lower part of figure 9) gives total body weight increments, which had different composition in individual years of our study, and varied also in individual groups. Lean body mass increased all the time, most in the third — fifth years of our investigation. The increments of lean body mass were greatest and appeared sooner in group I. Body fat increased most in the fourth — sixth year of study, later on decreased. Therefore, total body weight increments were e.g. in the third — fourth and sixth — eight years of our investigation smaller than lean body mass increments (fig. 9). Mentioned results of the densito-



9. Increases of fat and lean body mass in boys of different physical activity (groups I—III) from 10.6 to 17.7 years of mean age in individual years.



10. Development of individual skinfold thickness in of different physical activity (group I ———, group II — — —, group III ....) from 10.6 to 17.7 years.

metric analysis of body composition during development of boys with different physical activity demonstrate complicated growth changes during adolescence, which moreover vary due to different motor activity regimen. These changes would remain obscure without densitometric or any other body composition evaluations during longitudinal study (P a ř í z k o v á 1968 f, M a l i n a 1969).

When we evaluate these changes for the entire period of investigation (i.e. when we add increments for all years together) we find significant difference between relative and absolute increments of lean body mass especially when comparing group I and III.

There was no significant change in absolute amount of fat in group I (the increase in the last year only compensated the decrease one year before), and a significant increase of fat in group III. According to mentioned data the groups were graded after 1 — 2 years according to their physical activity: group I had relatively most marked development of lean body mass both in proportion both in absolute values. The reverse applied to depot fat — most marked development occured in group III.

XI. DEVELOPMENT OF SUBCUTANEOUS FAT AND ITS RELATIONSHIP TO TOTAL BODY FAT

There is a good agreement between the measurements of total proportion of depot fat on the one hand, and measurements of skinfold thickness using a caliper in children and adolescents (P a ř í z k o v á, 1961 b; 1963 a). In addition to densitometric appraisal of body composition we ascertained the skinfold thickness at various sites as mentioned in chapter III. The results are given in figure 10.

In the first year the skinfold thicknesses were approximately the same in all groups. During subsequent years the skinfolds did not increase in any of the groups. In the last year there were significant differences between group I and III. Greatest differences were found on the trunk, lesser ones on the extremities (fig. 10).

Comparing developmental trends from the first to the last year we can see that subcutaneous fat remained the same especially when the sum of ten skinfolds in group I was evaluated. This is in agreement with the conclusions on body composition measurements (fig. 8).

On the basis of skinfold measurements also the same circumferential measures in all groups can be elucidated: smaller development of muscular tissue was compensated by increased development of subcutaneous fat.

As was shown in our previous work, the relation between total and subcutaneous fat is different in the two sexes and varies also according to age (P a ř í z k o v á, 1962; 1963 b; P a ř í z k o v á et E i s e l t 1962). There is no significant difference between the regression body fat proportion on the sum of ten skinfolds in boys and girls 9 — 13 years old, and from 13 — 16 years the regression lines are also not different for the two sexes (P a ř í z k o v á, 1961 b). There is a significant difference between regression lines of the same relationship for boys younger and older than 13 years, and a significant difference between boys 13 — 16 years old and adult men (P a ř í z k o v á, 1963 b, 1968 a).

We calculated the coefficients of correlation between relative and absolute amount of body fat and skinfold thicknesses. Linear correlation was calculated; results are given in table 7. All correlations were statistically significant. Highest r values for the relationship with the sum of all ten, and with two (triceps, subscapular) skinfolds were found. In the first year only several significant relationships were proved for relative amount of body fat (Tab. 7). The values of r were then increasing from the first till fourth year, when the relationship between total body fat proportion and skinfold thickness was closest. More often significant relationships between relative amount of body fat and skinfolds were proved, but r values were mostly higher for the relationship between skinfolds and absolute amount of body fat (Tab. 7).

Simultaneously correlation coefficients of semilogarithmic and logarithmic relationships between amount of body fat and skinfolds were calculated; their values were nearly always lower than those of the linear relationship. Also in this case r values were highest in the fourth year of our study (P a ř í z k o v á, unpublished materials).

Since the linear relationship was closest in comparison with others, only linear regression equations are given in table 8. By means of these equations the proportion of total body fat from individual skinfolds, or either sum can be calculated. The individual error tends to be smallest when all ten skinfolds are measured. Consequently one can use regression equations (Tab. 8) or read directly the fat values from the nomogram (see figure 11).

When skinfold thicknesses with body fat proportion in a group with greater range of body fatness were correlated semilogarithmic relationship fitted best (P a ř í z k o v á 1961). But in a more homogenous group, with considerably lower average proportion of fat the optimal relationship was linear. This may be due to the fact that in obese subjects at a certain point the internal fat begins to increase considerably more than the external fat, so that the total proportion of fat is increasing without corresponding increase in subcutaneous fat. This is probably also the reason why e.g. r value of the correlation between fat percent and skinfolds were lower in the 5th year than in the preceding one (Tab. 7).

As regards the intercorrelations between skinfolds r values for the skinfold on the cheek and chin tended to be lowest. Highest r values were obtained for the skinfolds on the trunk (back, abdomen, hip). Neighboring (e.g. skinfolds on the thorax and on the back, on the hip and the abdomen, or two skinfolds either on the upper or lower extremity) showed high mutual correlations throughout (P a ř í z k o v á, unpublished data).

TAB. 7

Correlation coefficients (r) of the relationship between body fat in relative (%) and absolute (kg) amount of body fat and individual skinfold thickness and sum of ten or two of skinfolds*)

Years	1961		1962		1963		1964		1965		1966		1967		1968	
fat	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg
1 cheek	0.434			0.417	0.507	0.499	0.777	0.704			0.518	0.559	0.381			
2 chin		0.656	0.625	0.670	0.634	0.640	0.841	0.785	0.499	0.562	0.520	0.539	0.330		0.448	0.485
3 thorax 1			0.579	0.638	0.521	0.571	0.858	0.811	0.343	0.443	0.419	0.454	0.374	0.499	0.513	0.532
4 arm I (triceps)	0.491		0.549	0.645	0.498	0.488	0.856	0.790	0.566	0.637	0.364	0.388	0.563		0.533	0.560
5 subscapular			0.450	0.543	0.514	0.581	0.859	0.913	0.371	0.601	0.517	0.596		0.347	0.542	0.587
6 abdomen	0.382		0.650	0.719	0.721	0.771	0.933	0.912	0.593	0.728	0.637	0.689	0.601	0.594	0.625	0.662
7 thorax 2	0.419		0.595	0.686	0.646	0.712	0.888	0.932	0.499	0.698	0.559	0.598	0.481	0.581	0.579	0.621
8 hip (suprailiac)	0.354		0.576	0.672	0.598	0.677	0.856	0.920	0.465	0.637	0.627	0.660	0.558	0.595	0.655	0.694
9 thigh			0.494	0.566		0.372	0.588	0.621	0.377	0.539	0.437	0.512	0.540		0.632	0.674
10 calf			0.533	0.600	0.655	0.712	0.856	0.894	0.439	0.549	0.593	0.625	0.597	0.396	0.423	0.421
11 arm 2 (biceps)	0.409		0.510	0.634	0.722	0.763	0.831	0.804	0.548	0.638	0.476	0.473	0.477		0.682	0.705
Sum (1—10)			0.585	0.687	0.669	0.725	0.950	0.954	0.541	0.700	0.617	0.668	0.568		0.692	0.729
Sum (4—5)	0.405		0.546	0.650	0.549	0.587	0.933	0.940	0.523	0.690	0.479	0.534	0.512	0.364	0.564	0.602

*) only significant values are given ($p < 0.05$)

TAB. 8

Regression equations of the relationship between relative (%) or absolute (kg) of body fat (y) and sum of ten skinfolds (x)

Years	% fat (y) equation	s	kg fat (y) equation	s
1961	—	—	—	—
1962	$y = 6.232 + 0.127x$	4.68	$y = 1.568 + 0.063x$	1.66
1963	$7.182 + 0.139x$	3.31	$1.349 + 0.179x$	1.49
1964	$-0.764 + 0.173x$	0.51	$-1.557 + 0.107x$	0.29
1965	$5.230 + 0.134x$	3.63	$1.108 + 0.112x$	1.67
1966	$5.640 + 0.135x$	3.40	$2.540 + 0.107x$	2.23
1967	$2.664 + 0.150x$	2.75	—	—
1968	$0.304 + 0.133x$	2.64	$-0.785 + 0.110x$	1.85

x = sum of ten skinfolds

XII. STABILITY OF BODY COMPOSITION CHARACTERISTICS DURING PERIOD OF INVESTIGATION 1961—1968

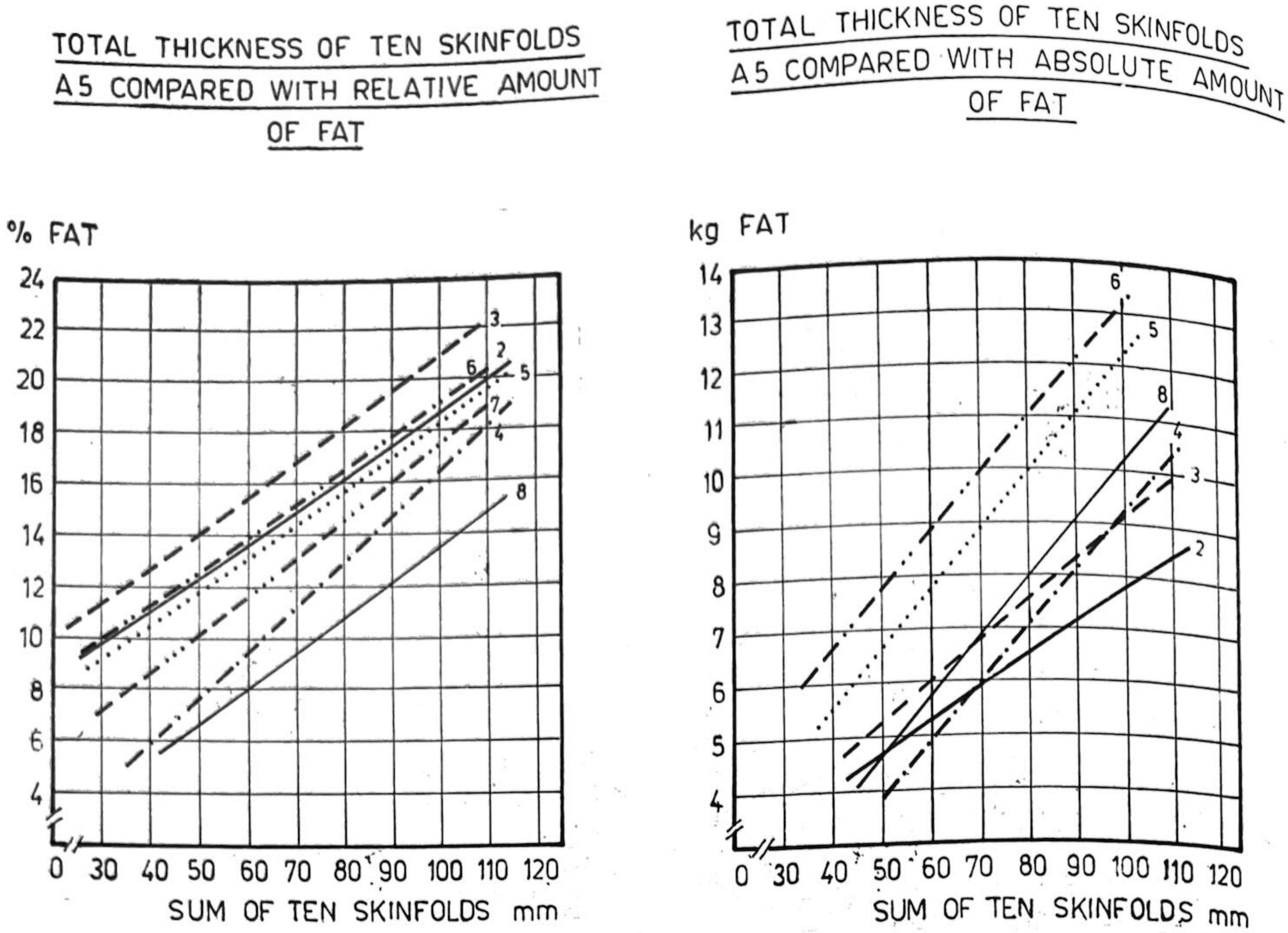
As followed from abovementioned data, trend of developmental changes of body composition and skinfolds had together with height and weight a constant character not only in individual groups but also in individual boys. For testing this stability the correlation analysis between selected results ascertained in the first and fifth, and first and eight years of our study was performed.

In figure 12. the correlation coefficients r of the relationships between the values measured in greater group of boys ($n = 96$ — Pařízková 1968; see chapter II.) in the first and fifth years are given. In the same figure also the correlation coefficients for a reduced group ($n = 41$) in which these relationships were followed both in the first and fifth, and first and eighth years are included.

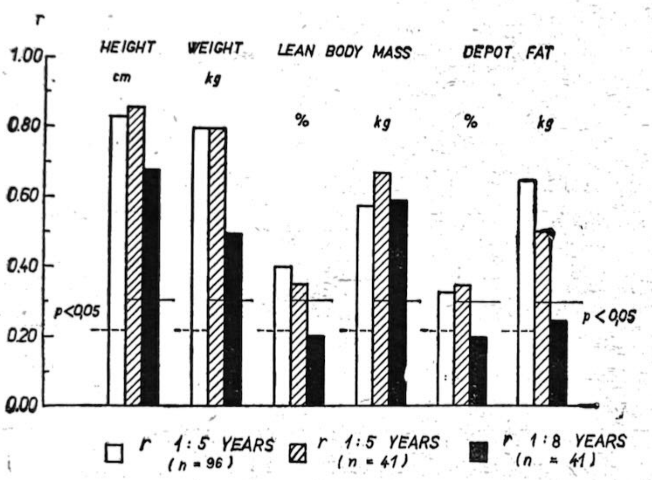
After shorter period all correlations for height, weight, relative and absolute amounts of lean body mass and depot fat were significant, i.e. boys who were taller, heavier, leaner or fatter in the first year tended also to be taller, heavier etc. in the fifth year of investigation. Highest r values for body height, weight, absolute amount of lean body mass and fat were found. Relative amount of lean body mass a depot fat correlated less closely. These conclusions apply both for greater and reduced group of boys in the same period (first and fifth years).

Correlation coefficients were markedly lower for the relationship between values measured in the first and eight years in 41 boys. Highest r values again for body height and absolute amount of lean body mass were found. Total body weight correlated less closely, what was obviously due to the lack of any relationship between amount of body fat in the first and eighth years. As follows the proportions of both main body components are markedly variable during mentioned period growth.

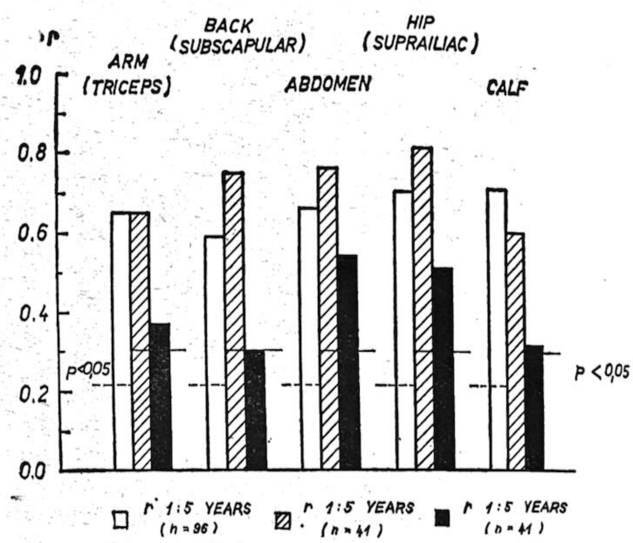
Subcutaneous fat seemed to be a fairly constant



11. Nomograms comparing thickness of the skinfolds with body fat proportion respective body density (a, left side) and absolute amount of body fat (b, right side) in boys of different physical activity, included in one group only. Regression lines were calculated for individual years (first year — 1, second year — 2, etc.).



12. Correlation coefficients r of the relationship between the values of somatic characteristics, measured in 41, resp. 96 boys in the first and fifth, and first and eighth years of the longitudinal study.



13. Correlation coefficients r of the relationship between the values of skinfold thicknesses measured in 41, resp. 96 boys in the first and fifth, and first and eighth years of the longitudinal study.

somatic characteristic in our boys too (fig. 13): correlation coefficients between values of most often measured skinfold thicknesses (Tanner 1962), i.e. on the arm (tricipital skinfold), back (subscapular skinfold), abdomen, hip (suprailiac skinfold) and on the calf were again higher for shorter period of observation. Skinfolds on the trunk had a tendency to correlate slightly more closely (especially skinfold on the abdomen and hip) than on the extremities. In all instances the correlations were significant, even between values measured in the first and eight years. The subcutaneous fat and its disposition on the body surface seem to display a greater stability than total amount of fat, both absolute and relative.

Mentioned results indicate, that not only basic somatic characteristics as body height and weight,

TAB. 9

The development of relative dimensions in boys ($n = 41$) during eight years

Years		1961	1962	1963	1964	1965	1966	1967	1968
$\frac{\text{Sitting height} \times 100}{\text{height}}$	$\bar{x}$	57.79	51.63	51.98	51.71	51.51	52.03	51.37	51.56
	SE	0.23	0.28	0.22	0.19	0.22	0.24	0.22	0.23
$\frac{\text{Biacrom. breadth} \times 100}{\text{height}}$	$\bar{x}$	21.42	20.65	21.32	21.64	21.62	21.94	21.92	22.03
	SE	0.18	0.17	0.13	0.13	0.16	0.19	0.12	0.12
$\frac{\text{Chest breadth} \times 100}{\text{biacromial breadth}}$	$\bar{x}$	70.08	70.10	68.16	65.43	72.05	74.41	73.04	74.58
	SE	0.57	0.68	0.66	0.64	0.98	0.91	1.09	0.96
$\frac{\text{Chest circumf.} \times 100}{\text{height}}$	$\bar{x}$	46.46	45.65	45.50	45.26	46.72	47.11	48.50	49.55
	SE	0.41	0.43	0.42	0.41	0.46	0.44	0.45	0.47
$\frac{\text{Chest circumf. expir.} \times 100}{\text{chest circumf. inspir.}}$	$\bar{x}$	92.00	93.64	90.85	90.16	90.33	99.32	91.09	92.02
	SE	0.34	1.60	0.27	0.31	0.36	0.41	0.37	0.41

but also absolute amount of lean body mass together with special disposition of subcutaneous fat represents in the period of adolescence constant characteristics of human physique, which under normal conditions keep stable trend of development. Relative amounts of both lean body mass and depot fat are on the contrary markedly variable, what is obviously due to their close dependence on energy balance and turn-over (determined mostly by nutrition and physical activity — Pařízková 1968 a, c, g), than on constitutional and hereditary factors.

XIII. DEVELOPMENT OF RELATIVE DIMENSIONS CHARACTERISING BODY BUILD

The rate of the increases in individual body dimensions was not uniform, as indicated by the relative change expressed as increase in percentage of initial values; the growing body has not been simply increasing, but has undergone simultaneously marked proportional changes.

In our preceding work (Pařízková 1961; 1966 a; 1967) including longitudinal studies (Pařízková 1964), we calculated a number of relative dimensions. We selected some of them for the present longitudinal investigation (Pařízková 1966 b). According to our previous experiences, these indices undergo marked changes in the course of growth and some have a significant relationship to body composition and functional indicators.

Changes in the relative dimension

$$\frac{\text{sitting height} \times 100}{\text{height}}$$

are given in table 9. Over the time this index decreased, but the changes were not very marked; in earlier periods of growth these changes are much larger (Grimm 1958). There were no significant differences among the groups with different physical activity.

Relative dimension

$$\frac{\text{biacromial diameter} \times 100}{\text{height}} \quad \text{(Tab. 9)}$$

remained the same during the whole period of our investigation except for the age of 11.6 years when it significantly decreased in all groups, and for the age of 17.7 years when it reached its highest values. This reflects a disproportion between the development of the height and breadth of the shoulders; at the time when total body height increased much more than the breadth of the shoulders (period of "springing up" — Harris 1947) the value of this relative dimension decreased, and vice versa at the end of our investigation. No influence of physical activity can be proved.

The relative dimension

$$\frac{\text{chest breadth} \times 100}{\text{biacromial diameter}} \quad \text{(Tab. 9)}$$

remained the same in the first and second year of our investigation in all groups. In the third year there was a decrease in its mean values; the breadth of the chest did not increase in the same rate as the breadth of the shoulders did. In the fourth year the decrease was still greater and statistically significant; the growth of the thorax was retarded according to the growth of the shoulders. This relative dimension was smallest in the fourth year of our investigation approximately; then increased and decreased again (tab. 9).

The relative dimension

$$\frac{\text{chest circumference} \times 100}{\text{height}}$$

after a slight decrease during the period of most rapid growth of body height, increased significantly only at the end of our study.

The relative dimension

$$\frac{\text{chest circumference exp.} \times 100}{\text{chest circumference insp.}}$$

decreased slightly after the second year of investigation, but at the end was identical to the first year (Tab. 9).

The development of the shape and relative breadth of the pelvis by means of two relative dimensions was evaluated. First of them

$$\frac{\text{bicristal breadth} \times 100}{\text{height}}$$

decreased slightly from the second to the third year, and more markedly from the third to the fourth year (Tab. 10), when pelvic breadth did not change at all, but total body height has been increasing persistently. During following years there appeared a significant increase of this relative dimension in all groups I — III. In the fifth year of investigation this increase was lowest in group I and highest in group III, i.e. the pelvic breadth increased relatively least in boys with highest physical activity and highest proportion of lean body mass. This difference manifested itself most markedly in the fifth year (Pařízková 1967, 1968 c, f).

The relative dimension

$$\frac{\text{bicristal breadth} \times 100}{\text{biacromial breadth}}$$

developed in a similar way (Tab. 10). In the fourth, fifth and eighth years there were significant group differences; group I with highest physical activity had relatively narrowest pelvic breadth. This type of body build was associated with increased proportion of lean body mass and higher level of aerobic capacity (Šprynarová 1966 a, b; Pařízková, Šprynarová 1967) and better physical fitness. Even when the pelvic breadth was corrected according to the thickness of subcutaneous fat, mentioned differences remained still significant.

In further two relative dimensions characterising breadth of the lower part of pelvis, viz.

$$\frac{\text{bitrochanteric breadth} \times 100}{\text{height}}$$

and

$$\frac{\text{bitrochanteric breadth} \times 100}{\text{biacromial breadth}}$$

(Tab. 11) no significant differences according to physical activity were found. First of these relative dimensions increased until the sixth year, and then remained approximately the same; the latter increased until the same age, but then increased more markedly. Biacromial breadth increased comparatively more (i.e. in relation to pelvic breadth) than

TAB. 10

The development of relative dimensions in boys ($n = 41$) during eight years

			1961	1962	1963	1964	1965	1966	1967	1968
Pelvic breadth × 100 / height	I.	$\bar{X}$	13.56	14.57	14.32	13.61	14.76	15.53	15.58	15.20
		SE	0.26	0.22	0.23	0.31	0.49	0.16	0.17	0.25
	II.	$\bar{X}$	13.88	14.57	14.19	13.65	15.72	15.76	15.79	15.29
		SE	0.18	0.16	0.18	0.17	0.19	0.23	0.14	0.24
	III.	$\bar{X}$	13.61	14.83	14.37	14.28	15.90	15.58	15.95	15.91
		SE	0.20	0.26	0.23	0.26	0.26	0.31	0.24	0.24
Pelvic breadth × 100 / biacromial breadth	I.	$\bar{X}$	64.74	70.92	68.20	62.21	68.04	70.74	71.45	68.98
		SE	1.50	1.14	1.25	1.46	1.14	1.06	1.06	0.86
	II.	$\bar{X}$	64.17	70.67	66.13	63.12	72.02	72.28	72.14	69.36
		SE	0.79	1.04	0.78	0.84	1.04	1.17	0.83	1.26
	III.	$\bar{X}$	63.77	72.32	67.86	66.83	75.04	70.75	72.81	71.81
		SE	0.91	1.50	1.28	1.12	1.60	1.35	0.81	0.96

TAB. 11

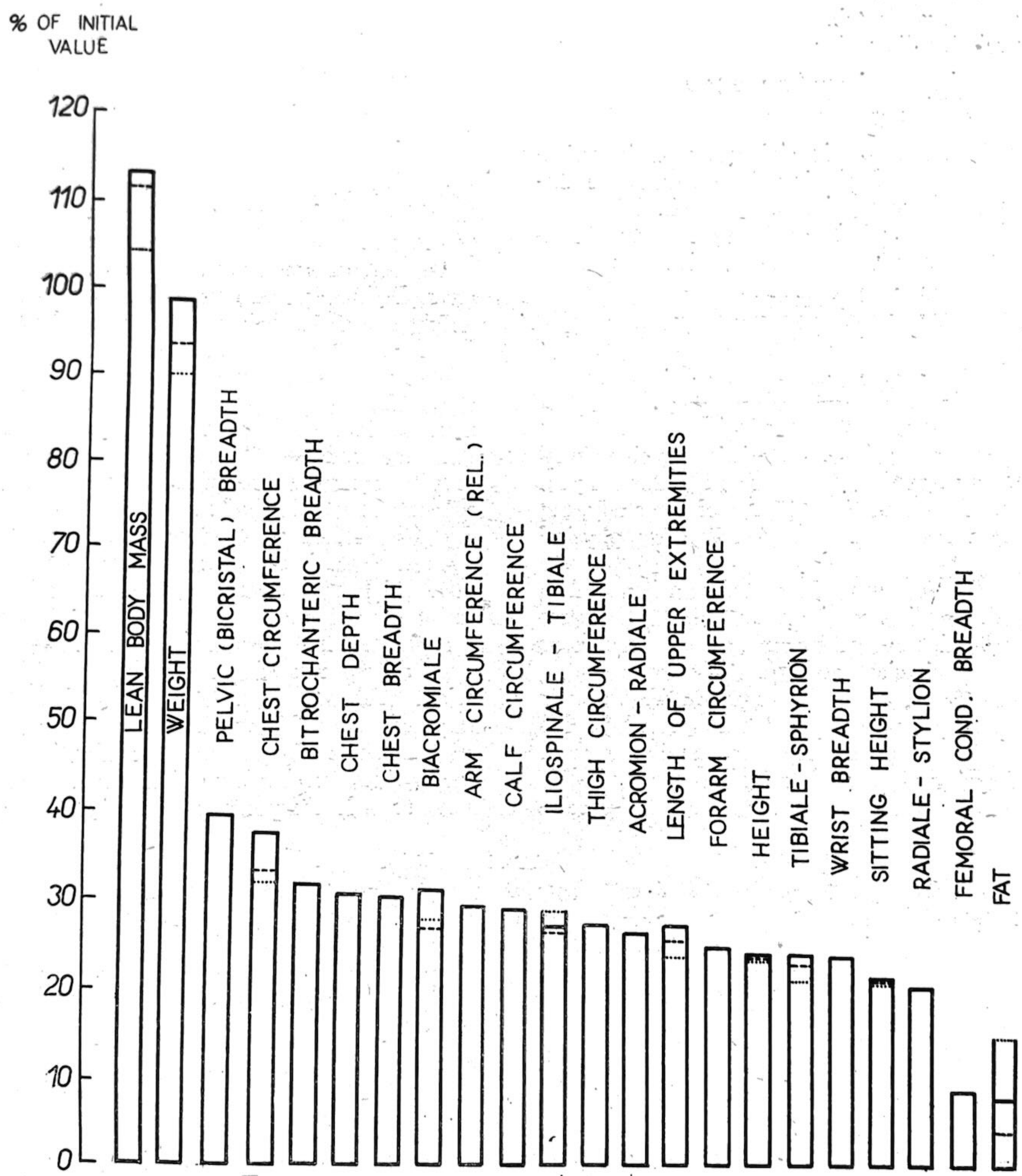
The development of relative dimensions in boys ($n = 41$) during eight years

Years		1961	1962	1963	1964	1965	1966	1967	1968
Bitroch. breadth × 100 / height	$\bar{X}$	16.95	16.60	17.37	17.46	18.09	18.15	18.28	18.03
	SE	0.14	0.15	0.14	0.19	0.15	0.15	0.19	0.12
Bitrochant. breadth × 100 / biacromial breadth	$\bar{X}$	79.26	80.47	81.38	80.72	83.81	82.97	83.47	81.94
	SE	0.72	0.64	0.67	0.88	0.76	1.04	0.85	0.69

TAB. 12

The development of relative dimensions in boys ($n = 41$) during eight years

Years		1961	1962	1963	1964	1965	1966	1967	1968
Calf circumf. × 100 / thigh circumf.	$\bar{X}$	67.96	67.97	68.29	68.53	68.53	69.58	69.49	68.85
	SE	0.52	0.62	0.58	0.55	0.55	0.53	0.94	1.14
Arm circumf. rest × 100 / arm circumf. contr.	$\bar{X}$	93.96	91.88	93.60	92.78	91.46	92.69	92.57	91.81
	SE	0.67	0.41	0.26	0.33	0.29	0.58	0.53	0.46
Forarm circumf. × 100 / arm circumf.	$\bar{X}$	102.67	101.48	99.74	100.85	99.17	99.36	97.01	95.60
	SE	2.06	0.94	0.74	1.01	0.87	0.81	0.74	0.80



14. Relative changes of individual anthropometric characteristics in boys of different physical activity (group I ———, group II — — — —, group III ....). In the cases when no significant differences among groups were found only mean value for all boys together is given. Ordinate = + percent of initial value.

body height during last two years of our investigation.

The relative dimension

$$\frac{\text{arm circumference (relax.)} \times 100}{\text{arm circumference (contract.)}}$$

can serve as an indicator of the functional state of the muscles better than a simple value of any individual circumference which is influenced both by muscle and subcutaneous fat development. The lower this relative dimension the better the muscle contractibility and function of muscles involved. Nevertheless, no significant differences in mean values of this dimension except the second, third and sixth year of investigation were found between groups with highest and lowest physical activity I and III. For that reason only mean values for all groups are given in tab. 12.

The relative dimension

$$\frac{\text{forarm circumference} \times 100}{\text{arm circumference}}$$

decreased significantly in eight years of investigation; only at the beginning there were some differences, but later on disappeared (Tab. 12).

Physical activity influenced only relative dimensions characterizing pelvic breadth, i.e.

$$\frac{\text{bicristal diameter} \times 100}{\text{height}}$$

and

$$\frac{\text{bicristal diameter} \times 100}{\text{biacromial diameter}}.$$

The others showed characteristic developmental changes, most marked from the 3rd to the 5th year and from the 7th to the 8th year of our study, but were the same in all groups regardless physical activity.

Boys who were most interested and involved in sport activites differed significantly in the 5th year in body build, i.e., had narrower pelvis than boys with lowest physical activity. As there were no significant differences in this regard in the first year of our investigation it is possible to account for this type of somatic development in the influence of physical activity: intensive muscular activity in this period of growth has changed not only body composition, i. e. soft tissues, but also had an impact on the proportionality of the skeleton. This is in agreement with previous findings on relatively broad pelvis of adolescent who were obese since childhood (P a ř í z k o v á, 1968 b). However it cannot be completely excluded that the differences can be due to other factors than physical activity. Constitution not only physical but also mental, determinated by genetic factors, could have influence on the development of behavior, hobbies and activities of our boys, which were later on associated with certain type of bodily development. Yet even in this case physical activity would be the immediately acting agent.

XIV. THE DEVELOPMENT OF THE RELATIONSHIP BETWEEN HEIGHT, WEIGHT, CHEST CIRCUMFERENCE TO OTHER SOMATIC INDICATORS

Trends and increases of some anthropometric measures were corresponding; the relationships between selected indicators and their changes with increasing age were therefore studied by correlation analysis in all boys together. First of all the relationships of height, weight and chest circumference to other selected dimensions were evaluated.

Correlation coefficients in tables 13 — 15 are given. Body height was more closely related to body weight and sitting height, than to the chest circumference; also length measures of the extremities correlated most closely with body height. Weight and chest circumference correlated best with length measures in the 3rd — 5th year of our investigation.

In tables 16 — 18 correlation coefficients with breadth measures are given. Biacromial breadth correlated best with body height; chest breadth and depth correlated most closely with chest circumference. Breadth of the wrist correlated best with body height, and breadth of the femoral condyles with body weight.

Circumferential measures (tables 19 — 21) were most closely related to total body weight. Body height (Tab. 19) correlated with circumferential measures only during the period of most rapid growth. Thigh circumference correlated with chest circumference and body weight (Tab. 20, 21).

As regards components, body height correlated

TAB. 13

Changes in correlation coefficients of the relationships between body height (cm) and various anthropometric measures in boys ($n = 41$) during eight years (only significant values are given)

Years	1961	1962	1963	1964	1965	1966	1967	1968
Weight	0.437	0.691	0.751	0.784	0.778	0.593		0.415
Sitting height	0.803	0.690	0.862	0.903	0.872	0.773	0.731	0.622
Length of upper extremities	0.737		0.937	0.941	0.828	0.814	0.840	0.804
Acromion — radiale	0.491	0.744	0.815	0.862	0.820	0.685	0.737	0.542
Radiale — stylion	0.572	0.714	0.795	0.771	0.709	0.329	0.688	0.721
Length of lower extremities		0.936	0.938	0.911	0.524		0.813	0.902
Iliospinale — tibiale		0.845	0.454	0.732	0.377	0.566	0.605	0.427
Tibiale — sphyrion	0.669	0.837	0.891	0.805	0.796		0.725	0.695

TAB. 14

Changes in correlation coefficients (r) of the relationships between body weight (kg) and different anthropometric measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Sitting height	0.544	0.630	0.806	0.814	0.819	0.750	0.450	0.590
Length of upper extremities			0.679	0.731	0.587	0.528		
Acromion — radiale		0.473	0.643	0.568	0.583	0.466		
Radiale — stylion		0.469	0.619	0.568	0.612			
Length of lower extremities		0.625	0.619	0.709				
Iliospinale — tibiale		0.599	0.426	0.566				
Tibiale — sphyrion	0.331	0.514	0.632	0.592	0.550			

TAB. 15

Changes in correlation coefficients (r) of the relationships between chest circumference (cm) and various anthropometric measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Height	0.380	0.392	0.480	0.681	0.629	0.291		
Weight	0.448	0.851	0.886	0.925	0.898	0.809	0.484	0.764
Sitting height	0.365	0.394	0.578	0.644	0.688	0.460		
Length of upper extremities			0.398	0.500	0.365			
Acromion — radiale			0.384	0.434	0.433			
Radiale — stylion			0.392	0.429	0.434			
Length of lower extremities		0.351	0.431	0.508				
Iliospinale — tibiale		0.343	0.339	0.413				
Tibiale — sphyrion	0.443		0.452	0.473	0.457			

TAB. 16

Changes in correlation coefficients (r) of the relationships between body height (cm) and breadth measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Biacromial breadth	0.546	0.515	0.786	0.780	0.693	0.457	0.595	0.527
Chest breadth	0.450	0.431	0.499	0.658	0.454			
Chest depth	0.372	0.414	0.424	0.405	0.515		0.326	0.230
Bicristal breadth	0.476	0.519	0.418	0.577	0.531		0.478	
Bitrochanteric breadth	0.655	0.690	0.795	0.726	0.773	0.580		0.549
Wrist breadth		0.481	0.753	0.786	0.700	0.446	0.469	0.407
Femoral condyles breadth	0.326	0.495	0.547	0.620	0.445			

TAB. 17

Changes in correlation coefficients (r) of the relationships between body weight and breadth measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Biacromial breadth	0.331	0.515	0.680	0.781	0.644	0.448		0.348
Chest breadth	0.536	0.646	0.778	0.783	0.549	0.674	0.342	0.374
Chest depth		0.485	0.498	0.561	0.643	0.502	0.485	0.482
Bicristal breadth		0.655	0.540	0.650	0.567		0.341	
Bitrochant. breadth	0.490	0.675	0.788	0.677	0.803	0.672		0.608
Wrist breadth	0.543	0.344	0.705	0.752	0.681	0.368	0.380	0.547
Femoral condyles breadth		0.657	0.784	0.788	0.367	0.612		0.439

positively with absolute amount of lean body mass only. Body weight also correlated positively with absolute amount of lean body mass and was less related to absolute amount of body fat (Tab. 22—24).

Between relative amount of lean body mass and body weight there was a significantly positive relationship only in the first year of our study. Chest circumference correlated both with absolute amount

TAB. 18

Changes in correlation coefficients (r) of the relationships between chest circumference (cm) and breadth measures ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Biacromial breadth	0.414		0.414	0.579	0.468		0.367	
Chest breadth	0.678	0.598	0.763	0.713	0.660	0.729	0.623	0.498
Chest depth	0.507	0.392	0.504	0.629	0.681	0.648	0.611	0.507
Bicristal breadth	0.422	0.475	0.454	0.600	0.515		0.461	
Bitrochanteric breadth	0.446	0.453	0.589	0.486	0.645	0.410	0.332	
Wrist breadth			0.463	0.564	0.527			
Femoral condyles breadth	0.576	0.479	0.617	0.711	0.563	0.593		

TAB. 19

Changes in correlation coefficients (r) of the relationships between body height (cm) and circumferential measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966
Chest circumference	0.380	0.392	0.480	0.581	0.291	
Arm circumference (right)		0.269	0.362	0.431	0.493	
Arm circumference (left)	0.242			0.379	0.463	
Forarm circumference		0.456	0.561	0.635	0.617	0.354
Thigh circumference			0.337	0.441	0.499	
Calf circumference	0.504		0.664	0.631	0.598	

TAB. 20

Changes in correlation coefficients (r) of the relationships between body weight and circumferential measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Chest circumference (rest)	0.448	0.851	0.886	0.925	0.898	0.809	0.484	0.764
Arm circumference — relax. (right)		0.792	0.810	0.847	0.875			0.682
Arm circumference — relax. (left)	0.546	0.765	0.765	0.815	0.855	0.767	0.397	0.619
Forarm circumference (right)	0.415	0.821	0.883	0.850	0.896	0.828	0.427	0.797
Thigh circumference (right)	0.500	0.756	0.821	0.838	0.874	0.846	0.447	0.838
Calf circumference (right)	0.616	0.540	0.902	0.887	0.844	0.765	0.487	0.793

TAB. 21

Changes in correlation coefficients (r) of the relationships between chest circumference (cm) and circumferential measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Arm circumference relax. (right)		0.767	0.805	0.893	0.875	0.857	0.742	0.725
Arm circumference relax. (left)	0.723	0.750	0.777	0.859	0.846	0.797	0.734	0.654
Forarm circumference	0.476	0.649	0.755	0.792	0.832	0.793	0.745	0.669
Thigh circumference	0.697	0.765	0.830	0.854	0.857	0.834	0.730	0.681
Calf circumference	0.611	0.514	0.767	0.817	0.776	0.733	0.435	0.590

TAB. 22

Changes in correlation coefficients (r) of the relationships between body height (cm) and relative as well as absolute amount of lean body mass in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Lean body mass %					0.296			
Lean body mass kg	0.544	0.753	0.808	0.897	0.844	0.663	0.587	0.598

TAB. 23

Changes in correlation coefficients (r) of the relationships between body weight and relative as well as absolute amounts of fat and lean body mass in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Fat %								0.326
Fat kg	0.716		0.517	0.437		0.465		0.450
Lean body mass %	0.616							
Lean body mass kg	0.925	0.821	0.893	0.922	0.926	0.852	0.480	0.800

TAB. 24

Changes in correlation coefficients (r) of the relationships between chest circumference (cm) and relative as well as absolute amounts of fat and lean body mass in boys ($n = 41$) during eight yers

Years	1962	1963	1964	1965	1966	1967	1968
Fat %	0.336	0.344	0.374		0.342		0.453
Fat kg	0.494	0.573	0.603	0.356	0.513		0.529
Lean body mass %		0.344	0.367				0.361
Lean body mass kg	0 606	0.732	0.768	0.795	0.624	0.677	0.475

of lean body mass and with body fat. Closest relationship at all between body weight and absolute amount of lean body mass was proved.

Height, weight and chest circumference were further correlated with selected relative dimensions; but only

$$\frac{\text{forarm circumference} \times 100}{\text{arm circumference}}$$

was significantly related to body weight and chest circumference.

All correlations mentioned differed significantly according to age: e.g. body height correlated most closely with length measures of the extremities and breadth measures in the 3rd and 4th years of our investigation (Tab. 13, 16). Circumferential measures had highest r values mostly in the 4th year of our study (Tab. 15, 18, 21) except absolute amount of lean body mass, which had highest r in the 5th year (Tab. 24).

Body weight correlated most closely with length measures in the 3rd and 4th year (Tab. 14), with breadth measures in the 4th and 5th year (Tab. 17) and with circumferential measures in the 5th year (Tab. 20). Lean body mass was closely related to body weight during the whole period; depot fat only in selected years (Tab. 23).

As follows both body height and weight proved close relationships to most dimensions measured. Height correlated best with length dimensions, weight with breadth and circumfedential measures. Period from 12. 2.—14. 2. years (3rd—5th year of study) i.e. the period of most rapid growth was the time when mentioned characteristics were related most closely. Before and after this period there existed obviously greater variability in the development of individual characteristics.

XV. THE DEVELOPMENT OF THE RELATIONSHIPS OF TOTAL, LEAN AND FAT BODY MASS TO SELECTED ANTHROPOMETRIC DIMENSIONS

In tables 25 and 14 correlation coefficients are given for the relationship between mentioned components of body mass and selected length measures. The comparison shows closer relationship of these dimensions to lean body mass (Tab. 25) then to total body weight (Tab. 14). No relationship to body fat as well as relative amount on lean body mass were proved.

TAB. 25

Changes in correlation coefficients (r) of the relationships between absolute amount of lean body mass (kg) and different length measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Age	0.643	0.278	0.280	0.326				0.354
Height	0.544	0.753	0.808	0.897	0.844	0.663	0.627	0.590
Sitting height	0.607	0.561	0.829	0.910	0.871	0.795	0.647	0.644
Length of upper extremities	0.441		0.749	0.847	0.661	0.611	0.388	0.369
Acromion — radiale	0.310	0.551	0.729	0.763	0.630	0.435	0.391	0.237
Radiale — stylion	0.264	0.543	0.609	0.624	0.622	0.435	0.286	0.364
Length of lower extremities		0.685	0.733	0.785	0.395		0.369	0.450
Iliospinale — tibiale		0.630	0.430	0.638				
Tibiale — sphyrion	0.378	0.634	0.663	0.652	0.594			

TAB. 26

Changes in correlation coefficients (r) of the relationships between absolute amount of lean body mass (kg) and breadth measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Biacromial breadth	0.364	0.656	0.700	0.842	0.693	0.479	0.565	0.563
Chest breadth	0.565	0.629	0.684	0.769	0.513	0.509	0.378	0.340
Chest depth	0.565	0.470	0.433	0.495	0.625	0.379	0.594	0.329
Bicristal breadth	0.331	0.607	0.527	0.651	0.548		0.568	
Bitrochanteric breadth	0.558	0.789	0.768	0.765	0.847	0.619		0.614
Wrist breadth	0.484	0.536	0.784	0.842	0.741	0.435	0.588	0.588
Femoral condyles breadth		0.600	0.685	0.784	0.641	0.507	0.399	

TAB. 27

Changes in correlation coefficients (r) of the relationships between absolute amounts of lean body mass (kg) and circumferential measures in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Chest circumference (rest)	0.381	0.606	0.732	0.768	0.795	0.624	0.677	0.475
Arm circumference relax.		0.570	0.578	0.638	0.755	0.682	0.509	0.488
Arm circumference contract.		0.583	0.658	0.720	0.754	0.712	0.618	0.482
Forarm circumference	0.379	0.732	0.794	0.825	0.842	0.789	0.766	0.621
Thigh circumference	0.445	0.454	0.540	0.629	0.683	0.620	0.592	0.533
Calf circumference	0.642	0.522	0.856	0.824	0.771	0.672	0.313	0.643

TAB. 28

Changes in correlation coefficients (r) of the relationships between relative amount of lean body mass (%) and circumferential measures in boys ($n = 41$) during eight years

Years	1963	1964	1968
Chest circumference (rest)	—0.344	—0.367	—0.361
Arm circumference relax.	—0.524	—0.506	
Arm circumference contr.	—0.431	—0.388	
Thigh circumference	—0.638	—0.521	—0.333

TAB. 29

Changes in correlation coefficients (r) of the relationships between absolute amount body fat (kg) and circumferential measures in boys (n = 41) during eight years

Years	1962	1963	1964	1965	1966	1968
Chest circumference (rest)	0.494	0.573	0.603	0.356	0.513	0.529
Arm circumference relax.	0.434	0.697	0.704	0.384	0.396	0.484
Arm circumference contr.	0.419	0.623	0.605	0.364	0.234	0.443
Forarm circumference		0.448		0.214		0.258
Thigh circumference		0.521	0.795	0.701	0.602	0.586
Calf circumference		0.369	0.375			0.364

TAB. 30

Changes in correlation coefficients (r) of the relationships between relative amount of body fat (%) and circumferential measures in boys (n = 41) during eight years

Years	1962	1963	1964	1966	1967	1968
Chest circumference	0.336	0.344	0.374	0.342		0.453
Arm circumference relax.		0.524	0.517			0.403
Arm circumference contr.		0.431	0.400			0.356
Thigh circumference	0.423	0.632	0.532	0.406	0.406	0.489

TAB. 31

Changes in correlation coefficients (r) of the relationships between absolute amount of lean body weight (kg) and selected relative dimensions in boys (n = 41) during eight years

Years	1962	1963	1964	1965	1966
Bitrochant. × 100 / height	0.465	0.385	0.348	0.489	
Bitrochant. × 100 / biacromial	0.429		0.325	0.387	

TAB. 32

Changes in correlation coefficients (r) of the relationships between proportion of lean body mass (%) and relative dimensions in boys (n = 11) during eight years

Years	1961	1962	1963	1964	1965	1967	1968
Chest circumf. × 100 / height			0.385	0.667	0.368	0.408	0.363
Calf circumf. × 100 / thigh circumf.	0.358	0.489	0.675	0.577	0.610		
Arm circ. rel. × 100 / arm contr.		0.339	0.551	0.446			
Forarm circ. × 100 / arm circ.			0.677	0.728			
Skinfold triceps + subscapular			0.549	0.935	0.523		0.433

TAB. 33

Changes in correlation coefficients (r) of the relationships between absolute amount of body fat (kg) and relative dimensions in boys ($n = 11$) during eight years

Years	1962	1963	1964	1965	1966	1967	1968
Chest circumf. × 100 / height	0.448	0.473	0.729	0.580	0.361	0.428	0.531
Calf circumf. × 100 / thigh circumf.	0.546	0.604	0.526	0.620	0.438	—	—
Arm circ. rel. × 100 / arm. circ. contr.	0.382	0.552	0.342	—	0.342	—	—
Forarm circ. × 100 / arm circ.	0.473	0.715	0.728	0.475	0.466	0.374	—
Skinfold triceps + subscapular	0.650	0.589	0.940	0.690	0.634	0.364	0.602

TAB. 34

Changes in correlation coefficients (r) of the relationships between proportion of body fat (%) and relative dimensions in boys ($n = 41$) during eight years

Years	1961	1962	1963	1964	1965	1966	1967	1968
Chest circ. × 100 / height	0.365	0.324	0.385	0.660	0.368			0.502
Calf circ. × 100 / thigh circ.	0.348	0.563	0.675	0.564	0.610	0.373		
Arm circ. rel. × 100 / Arm circ. contr.		0.330	0.551	0.450				
Forarm circ. × 100 / arm circ.		0.377	0.677	0.723		0.377	0.373	
Skinfold triceps + subscapular	0.405	0.546	0.549	0.933	0.523	0.479	0.512	0.564

In tables 26 and 17 correlation coefficients of the relationship to various breadth measures are presented. Biacromial breadth correlated best with absolute amount of lean body mass, but chest breadth, depth and bicristal breadth correlated more closely with total body weight (Tab. 17). Bitrochanteric breadth seemed to correlate better with absolute amount of lean body mass, but the difference was only slight. The wrist breadth correlated better with absolute amount of lean body mass, and breadth of the femoral condyles with total body weight (occasionally, as e.g. in the 5th year with the absolute amount of lean body mass). Body fat in absolute and relative amounts was related to breadth measures quite uniquely; the same applied for relative amount of lean body mass.

Body fat was significantly positively related to circumferential measures in the 3rd, 4th and 5th years (Tab. 29, 30); but correlation coefficients for the relationship of circumferential measures to total body weight were significantly higher (Tab. 20). In this case significant relationships were proved for relative amounts of both body compartments: for fat the relationship was positive, for lean body mass significantly negative (Tables 30 and 28). This applied especially for the circumference of the extremities in the 3rd and 4th year of our investigation.

The relationship of the chest circumference to lean body mass proportion was more marked in the 3rd, 4th and 8th year only (correlation was significantly negative — Tab. 28). Vice versa applied for depot fat proportion in the same age (Tab. 30).

Relative dimensions correlated mostly with the absolute amount of body fat (Tab. 33). Only very few correlations between relative dimensions and lean body mass were significant (Tab. 31). Total body weight correlated with relative dimensions irregularly and only occassionally.

There were again significant differences in r values according to the age. Lean body mass correlated most closely with length measures in the 4th year of our study, with breadth measures mostly in the 4th year, with circumferential measures in the 5th year and with the relative dimensions quite occasionally. Absolute amount of body fat correlated with circumferential measures most closely in the 3rd and 4th year of investigation and with relative dimensions also in the 4th year. Relative amount of lean body mass and fat correlated most closely with the circumferential measures in the 3rd year and with relative dimensions in the 3rd and 4th year of our investigation.

In summary lean body mass was most closely related to length measures, and biacromial, bitrochanteric and wrist breadth measures. These correlations were highest in the 4th and 5th year of our study. — Body fat was related only to circumferential measures and to selected relative dimensions characterising body proportionality, especially in the period when fat is increasing more markedly.

XVI. DEVELOPMENT OF THE RELATIONSHIP BETWEEN LEAN BODY MASS, BODY FAT AND FUNCTIONAL CHARACTERISTICS

Simultaneously with somatic development, the functional capacities of the organism change as well as shown in many cros-sectional (Robinson, 1938; Morse et al., 1949; Åstrand, 1952; Hollmann et Knipping, 1961) as well as longitudinal studies (Šprynarová et Reisenauer, 1965; Šprynarová 1966 a, b; Ulbrich 1966). These changes parallel the increase of total body weight (Rutenfranz, 1964).

Buskirk et Taylor (1956) compared in adult men relationships between maximal oxygen consumption and weight, lean body mass, active tissue and fat-free body mass, and always found higher correlations of maximal oxygen consumption with lean body mass than with total body weight. Further, in athletes maximal oxygen consumption was higher not only in the relationship to total body weight, but also to lean body mass, reflecting improved efficiency of respiratory and cardiovascular systems. — Close relationship between maximal oxygen consumption and body composition was confirmed also in young boys (Šprynarová et Pařízková, 1962) and older men (Fischer et al., 1965).

The relationship between body composition and functional indicators has shown clearly in children when marked changes in body composition occurred in a shorter period of time, e.g. in obese boys and girls who stayed in a special summer camp and decreased markedly their weight due to the reduction of excess fat (Pařízková et Vamberová, 1962). Increased physical activity in the camp changed not only the percentage of lean body mass (and of depot fat) but also oxygen consumption, ventilation, energy expenditure, and heart rate measured during and after the same optimal work load on a bicycle ergometer; we found a significant decrease of mean values of mentioned indicators when comparing results before and after reduction (Pařízková et al. 1962, 1965). The physical work was performed after reduction with much less energy expenditure, i.e. more economically than before.

In obese children the maximal oxygen consumption after weight reduction were primarily related to alternations in lean body mass, but not at all to fat changes (Šprynarová et Pařízková, 1965). — Oxygen consumption during optimal mean work load and maximal work load are related differently to weight and body components: the first seem to be more closely related to total body weight and its changes, the latter to absolute amount of lean body mass.

In a group of eleven-year old boys of normal population both maximal oxygen consumption (measured during graded work on a tread-mill till the moment of exhaustion) and proportion of lean body mass were ascertained (Šprynarová et Pařízková, 1962). Mean values of maximal oxygen consumption for this group was 1759 ml oxygen/min. what corresponded to mean values of other authors (Welch et al. 1959; Hollmann et Knipping, 1961). Maximal oxygen consumption was more closely related to lean body mass than body surface, body weight and height. — Further there was proved a significant correlation between lean body mass proportion and maximal oxygen consumption per kg body weight.

When various functional differences (oxygen consumption, absolute and in relation to total and lean body weight, studied at rest, during mean standard work load, and during graded maximal work load on a tread-mill) in groups differing in physical activity during initial five years (1961—1965) were tested a few significant differences were found during measurements at rest. More often but still only episodically they were found during aerobic work on the tread-mill (Šprynarová, 1966 a; Šprynarová et Reisenauer, 1966; Pařízková et Šprynarová, 1967; Šprynarová et Pařízková, 1967, 1968).

Under standard work load (60 and 85 Watts) on bicycle ergometer performed in the same manner each year no marked differences between groups in total oxygen consumption and most functional characteristics were found either at the beginning or at the end of five years investigation period. The task was easier for a 15-year old boy than for an 11-year old boy; consequently the mean values of pulse frequency significantly decreased during investigation period (Ulbrich 1967).

Differences indicating better physical fitness were most frequent during graded maximal work load on a tread-mill after two years of different physical activity (maximal oxygen consumption-relative and absolute, Pařízková et Šprynarová, 1967). In group I with the highest physical activity and percentage of lean body mass the highest values of maximal oxygen consumption in the 5th year (1st year — 1894.0 ml, SD $\pm$ 273.6; 5th year — 3592.0, SD $\pm$ 457.0) were proved in comparison with a group with lowest physical activity III (1st year — 1795.0 ml, SD $\pm$ 224.0; 5th year — 3223.0 ml, SD $\pm$ 465.0 — Šprynarová 1966 a, b).

After five years absolute increases in maximal oxygen consumption were significantly highest in group with highest physical activity. In increases of maximal oxygen consumption in relation to weight or to lean body mass there were no significant differences (Pařízková et Šprynarová, 1967; Šprynarová et Pařízková, 1968).

In table 35 and 36 the development of the relationships between maximal oxygen consumption, body weight and lean body mass in absolute and relative values during five years are presented.

Higher correlation coefficients with body weight in first two years (Table 35) were proved. Since third year the correlation has been always higher with absolute amount of lean body mass. There were no marked differences between values of cor-

TAB. 35

Changes in correlation coefficients (r) of the relationship between height (cm) and body surface (m^2) and oxygen consumption at rest, during standard and maximal work load in boys during five years

	1961		1962		1963		1964		1965	
	height	body surf.	height	body surf.	height	body surf.	height	body surf.	height	body surf.
O_2 consumption rest	0.330	0.398	0.477	0.512	0.504	0.642	0.581	0.639	0.375	0.494
O_2 consumption — work load: standard	0.459	0.696	0.508	0.751	0.555	0.822	0.687	0.849	0.527	0.754
O_2 consumption — work load: maximal	0.571	0.969	0.531	0.712	0.663	0.773	0.755	0.837	0.718	0.847

TAB. 36

Changes in correlation coefficients (r), of the relationship between total body weight and lean body mass (kg), and oxygen consumption at rest, during standard and maximal work load in boys during five years

	1961		1962		1963		1964		1965	
	weight	LBM	weight	LBM	weight	LBM	weight	LBM	weight	LBM
O_2 consumption rest	0.376	0.409	0.453	0.468	0.629	0.599	0.615	0.628	0.505	0.555
O_2 consumption work load: standard	0.722	0.680	0.765	0.610	0.862	0.806	0.861	0.812	0.790	0.721
O_2 consumption work load: maximal	0.661	0.599	0.692	0.680	0.731	0.779	0.804	0.868	0.821	0.850

TAB. 37

Changes in correlation coefficients (r) of the relationship between heart volume (ml) and body weight, respective absolute amount of lean body mass (kg) in boys (2th—5th year only)

Years	1962	1963	1964	1965
Weight	0.528	0.595	0.746	0.651
Lean body weight	0.687	0.654	0.698	0.744

relation coefficients of maximal oxygen consumption with weight and lean body mass in our boys as was proved by Buskirk and Taylor (1956) in adult men. But we can see a slight tendency for increasing r values with increasing age.

We considered further the relationship of maximal oxygen consumption with body fat in relative and absolute values. Body fat was in general negatively related to functional aerobic capacity. This was mostly marked in the second, third and fourth year of our investigation.

Indicators of functional aerobic capacity — maximal oxygen consumption and maximal oxygen pulse is closely related to the volume of the heart; this was proved not only in adults (Musshoff et al., 1962; Hollman et Venrath, 1963) but also in children (Čermák et al., 1965). The measurements of heart volume by roentgenography according to Musshoff et al. (1958, 1962) performed from 2nd to 5th years showed in our groups greater increase in the absolute volume of the heart in group I with highest physical activity in the third and fourth year of our investigation. Relative heart volume per kg body weight increased till fourth year of our investigation, then decreased significantly. There was a significant difference between groups differing extremely in physical activity, from the 2nd till 5th year of our investigation. In relation to lean body mass the heart volume was the same in all groups (Čermák et al., 1967).

The relationship of heart volume with weight and lean body mass is given in table 37. Correlation coefficients of the relationship of heart volume were more often higher with lean body mass. Only very few significant correlations of heart volume with body fat were proved. It seems therefore that the heart volume is more closely related to lean body mass than to total body weight, or body fat (Čermák et al., 1970).

We had no possibility to confront our data with corresponding results since we found no similar complex longitudinal study in children of this age. Longitudinal data on maximal oxygen consumption of our boys were in good agreement with cross-sectional values gained by other authors (Robinson, 1938; Morse et al., 1949; Åstrand, 1952; Ceretelli et al., 1963).

As follows from mentioned results, morphological development (especially of body composition and body build) is paralleled by corresponding development of functional indicators of physical fitness; all this is related closely to physical activity, and could be changed by different intensity of physical exercise, either spontaneous or imposed.

XVII. COMPARISON OF RELATIVE CHANGES IN ANTHROPOLOGICAL DIMENSIONS AND BODY COMPARTMENTS DURING EIGHT YEARS

Relative changes of all indicators measured were compared at the end of experimental period (fig. 14). Greatest change from all morphological characteristics measured occurred in absolute amount of lean body mass. The changes in all three groups studied are given. Next was the change in total body weight.

Bicristal breadth increased by 40 % approximatelly (only mean value is given for all groups as there were no significant group differences), chest circumference by 33 %. Next were breadth measures of the trunk — bitrochantric and chest breadth, and chest depth.

Relative change in biacromial breadth was again different in groups I. — III., as well as the length of iliospinale — tibiale dimension. The change was always highest in group I. with highest physical activity.

Length and circumferential measures changed mostly less then breadth measures during this period of growth. The lengths of more proximal segments of the extremities changed relatively a little more than the distal ones.

Total height increased comparatively little in this age period; sitting height increased less then total body height. Small changes we found in the robusticity of the skeleton breadth of the wrist and especially that of the femoral condyles; relative increase of the latter was lowest from all characteristics studied. There were great differences in the relative increments of body fat, as kg. It was slight in group I and II and considerably larger in group III.

As regards other indicators heart volume increased from 12 to 15 years aproximatelly in the same manner as total body weight in the same period (comparing mean values of the 2nd and 5th year; Čermák et al., 1967).

Functional aerobic capacity, i.e. maximal oxygen consumption (ml/min.) during graded work load on a tread-mill increased markedly (Šprynarová 1966 a, b), both considering the absolute and relative values (Pařízková et Šprynarová, 1967). It seems that from functional point of view the growing organism changed from the first to the fifth year of our investigation period more than from morphological one. Closest to changes in functional aerobic capacity were in this period the changes in absolute amount of lean body mass, which increased most from all morphological characteristics.

XVIII. SUMMARY AND CONCLUSIONS

Somatic development and body composition were studied longitudinally in eight subsequent years (1961—1968) in a group of the same boys ($n = 41$) from the mean age of 10.7 to 17.7 years. The subjects lived with their families in a large city under approximatelly identical conditions of life (same type of public schools, social background, nutritional and hygienic conditions). Boys were divided into three subgroups according to their physical activity, evaluated by means of questionnaires and, in boys highest physical activity (group I) also by direct check of their activities in sport clubs. Subjects in group I were engaged for more than six hours per week in systematic and intensive physical exercise and participated regularly in summer training camps. On the other hand, boys of group III had least physical activity lasting in the mean two hours and a half per week, including physical education at school which was the same for all boys. Group II was intermediary.

During the period of investigation lean body mass increased relatively most (+ 104.7–113.6 % of the initial value ascertained in the first year), together with total body weight (+ 89.6–98.5 %). Breadth measures of the pelvis (bicristal and bitrochanteric diameters) increased approximatelly by 39.9 % and 31.8 % respectively, the chest circumference by 33.4 %. Length dimensions and circumferences of the extremities changed less (+ 21.1 to 28.8 %). The lengths of the more proximal segments increased a little more than distal ones. Body height increased by 23.8 – 24.3 %, sitting height by 20.8 to 21.4 %. Smallest change occurred in the indicator of the robusticity of the skeleton, i.e. breadth of the femoral condyles (+ 8.8 %), as well as in body fat (+ 8.2 to 15.3 % of initial value).

Some of the characteristics changed nearly linearly until 7th – 8th year of our investigation (i.e. until 16.6 – 17.7 years), as e.g. sitting height, leg circumference etc. Most of the characteristics changed least from the 1st to the 2nd year (10.6 – 11.6 years of mean age), and most from the 4th to the 6th year (13.2 – 15.7 years) as e.g. length and circumferential measures of the extremities, chest breadth and chest circumferences. Biacromial diameter, chest depth and bitrochanteric diameter changed only slightly from the 1st to the 2nd year, but were increasing nearly linearly later on. Bicristal diameter increased mainly from the 1st to the 2nd and from the 4th to the 6th year. Robusticity of the skeleton (wrist and femoral condyles breadths) changed more markedly from the 3rd to the 4th (12.2 to 13.3 years) and from the 7th to the 8th year our investigation only.

Various aspects of body build and proportionality changed to a different degree during investigation period. Relative length of the trunk evaluated as

$$\frac{\text{sitting height} \times 100}{\text{height}}$$

decreased slightly throughout the whole period. Relative shoulder breadth

$$\frac{\text{biacromial diameter} \times 100}{\text{height}}$$

has been increasing slightly until last year except for a temporary decrease in the 2nd year. Relative breadth of the pelvis

$$\frac{\text{bicristal diameter} \times 100}{\text{height}}$$

and

$$\frac{\text{bicristal diameter} \times 100}{\text{biacromial diameter}}$$

increased until 2nd year, decreased between 2nd and 4th year and increased again until 7th year. Relative dimension

$$\frac{\text{bitrochant. diameter} \times 100}{\text{height}}$$

decreased from the 1st to the 2nd year, then increased steadily until 7th year. Relative dimension

$$\frac{\text{chest breadth} \times 100}{\text{biacromial breadth}}$$

decreased until 4th year (13.2 years of age) and then increased again to the values slightly higher then initial ones.

According to different physical activity, boys who were mostly interested in systematic physical exercice and endured in training during whole investigation period (group I) were always tallest. This was mostly due to longer lower limbs. Body weight was significantly higher starting with the 7th year in group I, biacromial breadth from the 4th – 7th year of our investigation as compared to group III. Length of the upper extremities and chest circumference were significantly greater in boys of group I in the last year only.

There was a significant difference in the development of body composition, which was the same in the 1st year: in boys of group I the relative and absolute amount of lean body mass increased significantly more than in the boys of group III (2nd – 8th year of investigation). Analysis of covariance did not prove any relationship of lean body mass to body height. The relative amount of body fat significantly decreased in group I and the absolute amount of body fat remained the same. In group III the relative amount of fat decreased less, the absolute amount increased.

Measurement of ten skinfold thicknesses by a caliper (on the cheek, chin, two sites of the thorax, back, arm, abdomen, hip, thigh and calf) did not reveal marked increase of skinfold thicknesses in any group. Selected skinfolds were greater in boys of group III (abdomen, hip etc.). A significant relationship between relative and absolute amount of total fat and skinfolds, both individually and summated (sum of ten or two skinfolds) were proved, and regression equations were calculated for individual years.

The developmental trend of the absolute amount of lean body mass as well as of individual skinfolds had a characteristic stability during investigation period similarly as total body height: significant relationships (proved by correlation analysis) among values ascertained in the 1st and 5th, and 1st and 8th years were found.

As regards body build, boys of group I had in the 5th year a relatively narrower pelvis in comparison with boys of group III: relative dimensions

$$\frac{\text{bicristal diameter} \times 100}{\text{height}}$$

and

$$\frac{\text{bicristal diameter} \times 100}{\text{biacromial diameter}}$$

were significantly lower in group I. In other relative dimensions no significant differences were found.

All differences found among groups with different physical activity were mostly marked at the age 13.2 — 14.2 years, i.e. in the 4th and 5th years of our investigation, when also spontaneous physical activity was mostly different in individual groups (i.e. highest in group I); later on the differences were less marked.

Selected characteristics and relative dimensions were correlated with body height, weight, chest circumference and absolute and relative amounts of lean body mass and depot fat. These correlations were calculated far all boys together to examine developmental trends in the relationships between variables.

Body height correlated most closely with length measures and breadth of the wrist; body weight with breadth and circumferential measures. Both height and weight correlated positively with absolute amount of lean body mass. Chest circumference correlated significantly positively with height as well as weight.

Lean body mass was most closely related to length and selected breadth measures (biacromial, wrist and femoral condyles breadths). Chest breadth, depth and bicristal breadth correlated better with total body weight. Body fat correlated best with circumferential measures of the body. Lean body mass proportion correlated significantly negatively with circumferential measures, fat proportion positively. Only selected relative dimensions correlated significantly with absolute amount of body fat.

All correlations mentioned were mostly closest in the 3rd — 5th year of our investigation, i.e. at the age of 12.2 — 14.2 years.

Further there was a paralelism between the development of lean body mass and that of functional aerobic capacity, measured as maximal oxygen consumption during graded work on a tread-mill. Boys of group I who had highest relative and absolute amount of lean body mass had also highest absolute and relative functional aerobic capacity (in relation to weight and lean body mass). There was a significantly positive relationship between lean body mass and functional aerobic capacity development; the reverse applied for body fat.

For testing physical fitness of adolescents from morphological point of view first of all body composition measurements by means of densitometry or by other suitable methods could be recommended in addition to height, weight, chest circumference measurements etc. Skinfold thickness measurements by calipers using nomographs for calculation of body fat and lean body mass are suitable for field studies. Relative dimensions characterising body build are helpful also, especially those relating pelvic breadth to body height and to biacromial breadth. Other anthropometric characteristics according to data mentioned do not seem to be influenced by physical activity and, consequently, linked with better physical fitness characterised most effectively in terms of functional aerobic capacity.

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