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LONGITUDINAL STUDY OF DEVELOPMENTAL CHANGES IN LENGTH, BREADTH AND CIRCUMFERENTIAL MEASURES IN ADOLESCENT BOYS WITH VARIOUS PHYSICAL ACTIVITY

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Different parts and dimensions of the human body develop in various manners during growth — especially during praepuberal acceleration of growth. Abel (1940), Harris (1947) et al. mention e. g. periods of "springing up" and "filling out"; on the other hand Bocheňska (1958) concluded on the basis of her cross-sectional measurements of height, weight, shoulder circumference and skinfolds that periods of increased growth in height are paralleled by greater increases in weight. More exact analysis of the relationships between the increasing of individual dimensions and indicators can be made by using longitudinal data gained during longer periods of ontogeny in the same subjects.

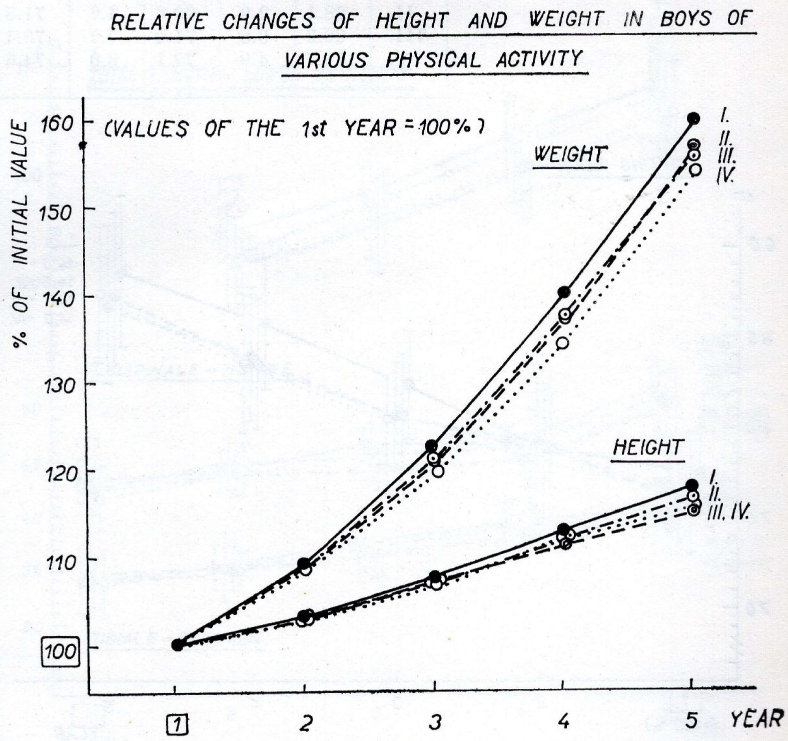
Systematic muscular activity and exercice in growth period is supposed to be an important factor which could change to certain extent somatic development. This problem has been studied by Schwartz et al. (1928), Arnold (1941), Tanner (1952); but most of the studies are cross-sectional, or of short duration only (several months). Therefore they cannot differentiate dependably simultaneous impact of heredity and constitutional factors, seasonal influences, social background etc. from the true consequences of increased activity and sports.

In a longitudinal study of boys from 11 to 15 years we tried to analyse both these problems — relative increase and growth trend of different selected anthropometric measures, resp. their changes due to various intensity of physical activity in this age period.

METHODS

96 normal healthy boys of Czech population were followed longitudinally starting in 1961 at the age of 11 years. The subjects lived in a city of 1 million of inhabitants with sufficient transport 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 individual experimental groups. Boys of subgroup I. trained regularly during the whole experimental period in sport schools, and moreover participated individually in some additional sport activity; this amounted to more than six hours of intensive regular physical exercice per week. In addition, the subjects participated in special summer camps of four week duration. In subgroup II. the boys trained regularly in the sport schools only during all experimental period. Boys from subgroup III. trained in sport schools or other sport clubs irregularly. Boys with relatively limited physical activity (subgroup IV) exerciced less than two years irregularly during the period from 11 to 15 years.

All measurements were performed (always after thorough clinical examination) in spring, mostly in April and May. The anthropometric measurements,



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described by Martin (1928) included: height, weight, sitting height, length of the upper and lower extremities and their segments, circumferences 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 dimensions), chest breadth and depth, circumferences of the chest at rest, expiration and inspiration, breadth of the wrist and femoral condyles. In addition the relative and absolute amount of lean body mass was ascertained by means of densitometry (Keys and Brožek 1953; Pařízková 1959, 1961).

RESULTS

Mean values of height and weight are given in table 1. No significant differences between individual groups according to physical activity were found. Comparison with Czech (Kapalín et al. 1957), American (Wetzel 1942) and English standards (Tanner et al. 1966) did not reveal any differences as well, i. e. our boys represented physically an average of boys population in this age period. Relative changes of height and weight in individual groups and years are presented separately in fig. 1. also in this case no significant differences among groups were proved.

TABLE 1

	1		2		3		4		5	
	x	SD	x	SD	x	SD	x	SD	x	SD
Height										
I.	147.2	3.5	152.3	3.8	158.7	4.9	168.5	5.9	173.3	5.4
II.	145.5	6.7	150.6	7.9	156.5	7.6	163.7	8.6	170.3	7.8
III.	144.6	6.7	149.1	5.6	154.1	5.4	161.8	6.3	168.7	6.6
IV.	144.4	5.2	149.3	5.7	154.5	6.4	161.4	7.3	169.6	7.0
Weight										
I.	37.6	4.0	40.8	3.7	46.4	5.0	52.7	7.2	60.4	7.1
II.	35.8	4.3	39.3	5.1	43.4	6.2	49.2	7.3	55.9	7.7
III.	36.6	4.7	40.1	4.8	44.0	5.5	50.5	6.7	57.7	6.2
IV.	38.4	6.0	42.3	7.2	46.0	7.7	51.6	8.6	59.5	9.6
Chest circumference (rest)										
I.	69.8	2.7	71.7	3.5	74.1	2.7	78.1	3.9	83.7	4.2
II.	68.1	2.9	69.6	4.2	71.8	3.8	75.3	4.3	80.4	4.9
III.	69.0	3.8	71.2	4.2	73.4	4.9	77.1	4.9	82.4	5.1
IV.	70.7	4.9	72.1	6.0	74.5	6.01	77.6	6.1	83.1	5.9

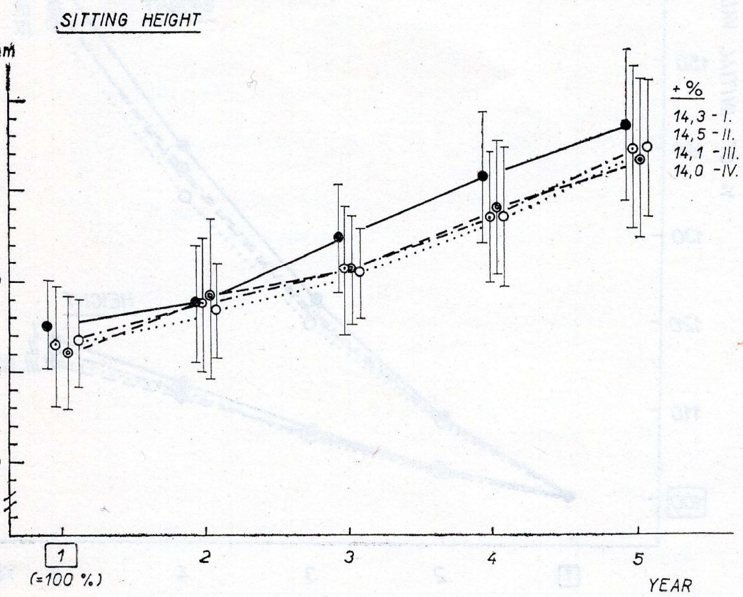

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Fig. 2 shows no differences in the development of sitting height in individual groups — the length of the trunk increased in the same manner in all groups. The relative change in this dimension expressed as percent inscrease of initial value at the age of 11 (equalling 100 %) is given on the right side of the curves (+%). This relative change is also the same in all groups (14,0—14,5 %).

Total length of upper extremity, dimension acromion-radiale and radiale — stylion are presented in fig. 3. Also in these measures there are no differences according to physical activity, as well as in total length of lower extremity and its segments (fig. 4). Extremities increased relatively in their dimensions very similarly as total and sitting height, and much less than e. g. weight (see fig. 1.).

The development of the circumferences of the extremities is presented in fig. 5 and 6. We expected some differences due to increased muscular work in boys of subgroup 1., but nothing was proved in this respect; mean values of all circumferential measures at relaxation as well as at contraction were the same in all groups. Relatively greatest developmental change in arm circumference occured from 14 to 15 years; the mean values in the last year were larger by + 16,5 to 22,2 % than in the first year. The forarm circumference increased almost linearly, after temporary stagnation, from 12 to 15 years. As in length dimensions, the relative developmental changes of the forarm as a more distal segment are relatively smaller than those of the more proximal (arm) with mean developmental values being +13,3 bis 15,2 % (fig. 5).

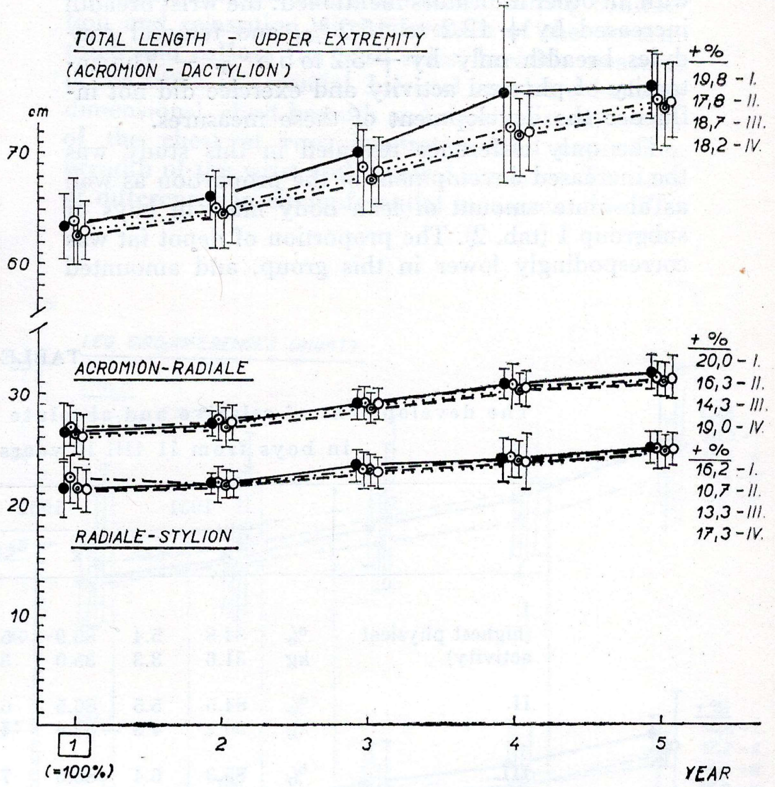
From 11 to 14 years the development of the thigh circumference was linear. The overall increments were + 13,7 to 19,3 % of initial value. Calf circumference increased at the same rate in all groups during the five years; final increments were +16,8 bis 19,6 % of initial value (fig. 6). In comparison with relative changes of the thigh circumference, this increase was approximately the same. — All circumferential dimensions increased relatively least in the first year (i. e. from 11 to 12 years) and relatively greatest in the last year, i. e. from 14 to 15 years.

Very important indicators of somatic development and fitness are the chest dimensions. Breadth measures of the chest are presented in fig. 7 : biacromial and transversal chest diameters as well as chest depth developped identically in all mentioned subgroups differing in physical activity. The same applies for chest circumferences — at inspiration and expiration (fig. 8). When calculating respiration range (differences between chest circumference at inspiration and expiration) we proved the same increase in all groups.

The index $\frac{\text{circumf. expir.} \times 100}{\text{circumf. inspir.}}$ decreased slightly (by −0,7—4,0 %) indicating also that the increase in inspiration circumference was relatively greater than of expiration circumference (see fig. 8). The increase in the respiration range was therefore due not only to the general increase of the thorax, but also of its expansion ability in this age period.

Development of pelvis was followed by measuring two breadth measures — bicristal diameter (upper part growth) and bitrochanteric diameter (lower part growth). The results are given in fig. 9 : the developmental trends are not identical. Bitrochanteric diameter increased steadily after temporary stagnation from 12 to 15 years, in total by + 24,3 to 27,0 % of initial value. The bicristal diameter increased only during the first year from 11 to 12 years (and then during the last year (from 14 to 15 years), in total by + 27,5 to 33,8 % of initial value. The influence of increased physical activity was not manifested in the development of pelvic dimensions, there were slight differences in the last year in the bicristal diameter which was a little lower in subgroup I. in comparison with group IV, but this difference in absolute values was not significant.

The development of the robusticity of the skeleton was followed by measuring the breadth of the wrist and of femoral condyles (fig. 10). In this case the relative changes were smallest in comparison



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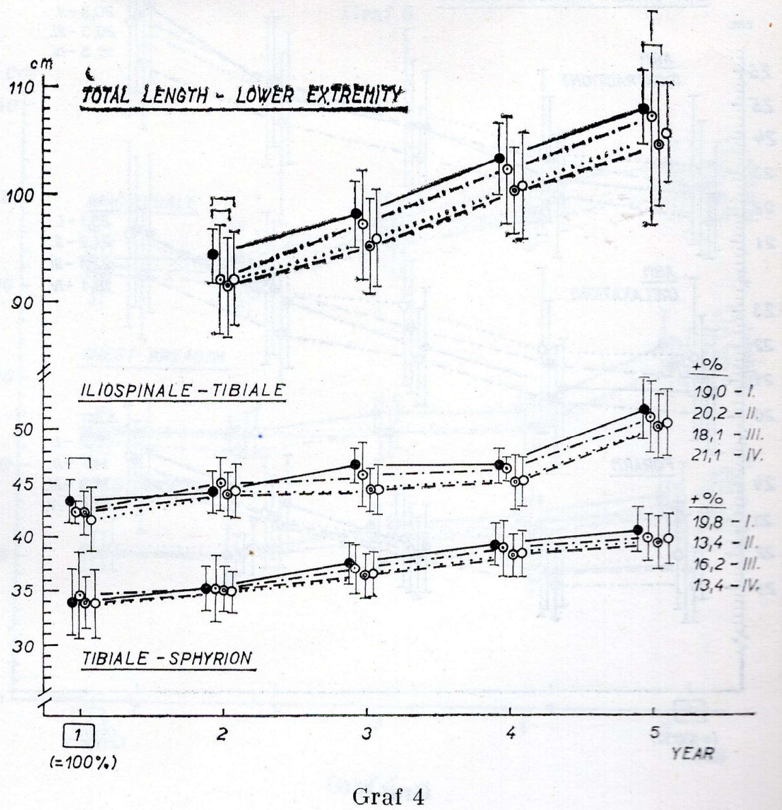


Graf 4

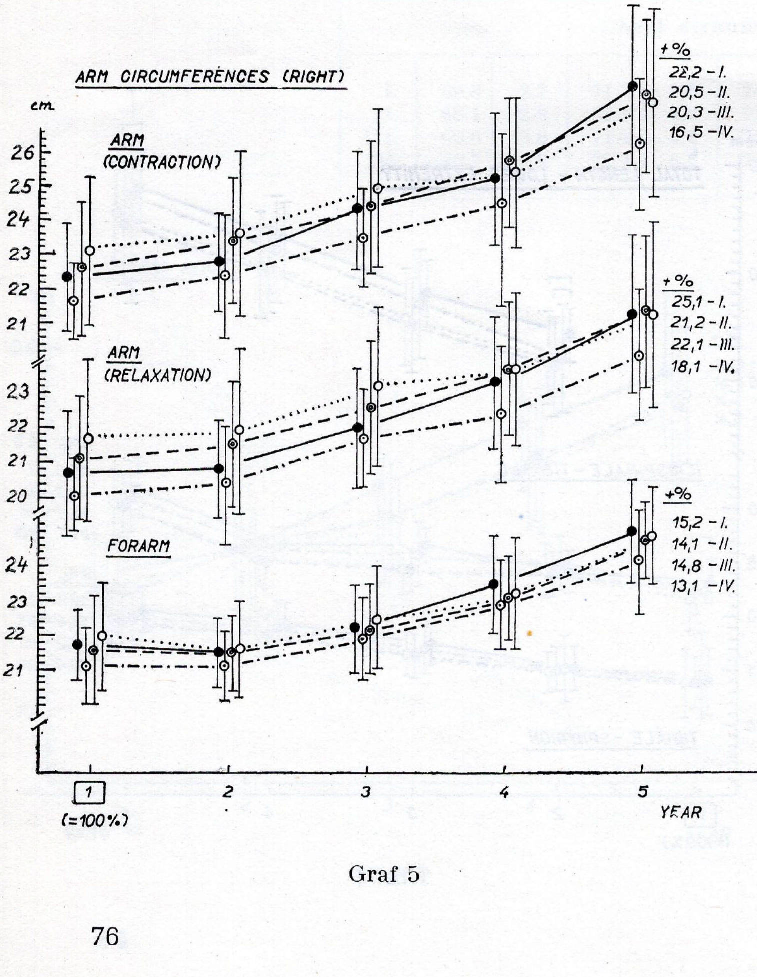
with all other indicators mentioned: the wrist breadth increased by + 12,2 to 15,2 %, and femoral condyles breadth only by + 3,2 to 5,5 %. — The intensity of physical activity and exercice did not influence the development of these measures.

The only difference revealed in this study was the increased development of the proportion as well as absolute amount of lean body mass in boys of subgroup I (tab. 2). The proportion of depot fat was correspodingly lower in this group, and amounted the highest values in last group with relatively lowest physical activity (Pařízková 1968 a, b, c).

TABLE 2

The development of relative and absolute amount of lean body mass (% and kg) in boys from 11 till 15 years followed longitudinaly

		1961		1962		1963		1964		1965	
		x	SD	x	SD	x	SD	x	SD	x	SD
I. (highest physical activity)	%	84.8	5.4	85.9	5.7	87.3	4.8	90.3	3.1	90.1	3.3
	kg	31.6	3.3	35.0	3.8	40.4	5.4	45.5	6.8	54.3	7.1
II.	%	84.5	5.5	86.5	6.1	87.6	4.8	88.6	9.4	87.5	4.2
	kg	30.2	4.3	33.8	4.5	37.9	5.3	44.1	7.2	49.1	8.3
III.	%	85.3	6.4	85.5	7.5	85.5	2.3	97.5	5.8	86.4	4.2
	kg	31.0	3.1	34.1	3.4	37.3	3.6	43.9	5.1	49.7	5.4
IV. (lowest physical activity)	%	82.7	6.2	80.9	6.1	83.1	5.9	85.3	4.4	84.1	5.3
	kg	31.4	3.3	33.8	3.9	37.8	4.6	43.8	6.3	49.8	6.6



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DISCUSSION

Longitudinal studies of growth (height, weight) were made in various countries including USA (Stuart and Reed 1951; Falkner 1964 etc.), England (Tanner 1964), France (Sempé et al. 1964), Belgium (Adiel 1964) and Sweden (Karlberg 1964). At present these studies are coordinated by the Centre International de l'Enfance in Paris. Measured indicators are mostly height, weight, chest circumference, skinfolds etc. The influence of exercice on somatic growth has been studied to a limited extent. Some authors (e. g. Schwartz et al. 1928, Arnold 1930, Correnti 1941) described increased rate of growth due to physical exercice but Tanner (1962) felt that define conclusions would be premature; primordial selection of better developped children (interested therefore more in exercice) could be the reason of these differences in cross-sectional studies. Our longitudinal study starting with the children of the same height and weight did not prove enhanced growth due to increased physical activity.

Changes in the growth of upper and lower extremities, in relation to adult values were reported by Simmons (1944). — Increased physical activity during growth did not influence length dimensions of the extremities.

The lack of differences in circumferential measures of the extremities (which are supposed to be a consequence of the adaptation to increased physical activity) could be elucidated by the fact that hypertrophy of the musculature is compensated by decreased layer of subcutaneous fat, as proved by measuring body composition. Increased values of arm etc. circumferences in comparison with untrained subjects is therefore not necessarily a characteristic of a trained adolescent.

Also the circumference of the chest — at rest, inspiration and expiration as well as the respiration range and mentioned index

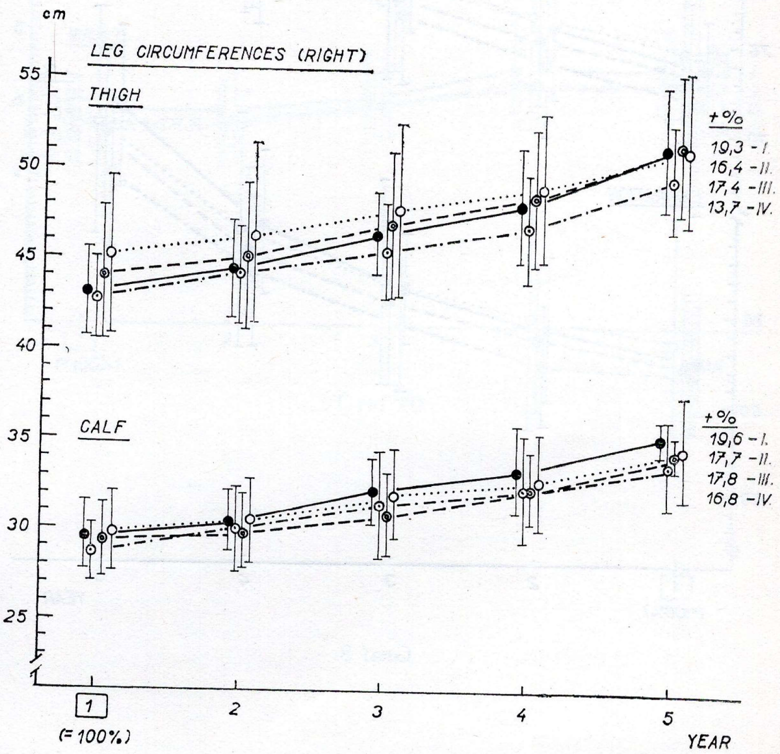
$$\frac{\text{chest circ. exp.} \times 100}{\text{chest circ. insp.}}$$ are not necessarily

influenced by the intensity of physical exercice. In our groups which differed significantly in body composition — increased development of lean body mass at the expense of fat (Pařízková 1967, 1968) together with increased functional aerobic capacity (measured as maximal oxygen consumption during graded work load on a horizontal treadmill - Šprynarová 1966; Pařízková and Šprynarová 1967) these dimensions were identical, and did not differentiate subjects with different physical fitness.

Longitudinal measurements in the same subjects during the period from 11 to 15 years enabled more exact evaluation of relative changes and trends in various anthropometric measures. During the investigation period the absolute amount of lean body mass increased relatively most, i.e. by + 65 % of the mean initial value ascertained at the age of 11 years, together with total body weight (by + 56 %). Respiration range increased by 31 %, breadth measures of the pelvis (bicristal and bitrochanteric diameters) increased approximately by 28 % and 24 % respectively, and the chest by 20 %. Length dimensions and circumferences of the extremities changed less (by + 15—20 %). The length of the more proximal segments increased a little more than distal ones. Body height increased by + 15 to 18 %, sitting height by 14 to 14,5 %. Smallest changes from 11 to 15 years occured in the indicators of the robusticity of the skeleton — breadth of the wrist (+ 12,2 to 15,2 %) and femoral condyles (+ 3,2 to 5,5 % of initial value). Some of the characteristics changed linearly during the whole period (e.g. sitting height, leg circumferences) but most of them changed least from 11 to 12 years, and most from 14 to 15 years (e.g. weight, dimension iliospinale — tibiale, arm circumferences, chest breadth and chest circumferences). Therefore, body build and proportionality changed during mentioned period also to a different degree.

SUMMARY

A group of 96 boys subdivided according to the intensity of physical activity into four subgroups (group I. — most intensive physical activity, group IV. — relatively inactive) was followed from 11 to 15 years. In the first year there were no differences in all indicators measured. Both at the age of eleven and fifteen years (i.e. after four years of different physical activity) there were no significant differences in body weight, height, sitting height, length measures of upper and lower extremities and their segments, circumferences of the arm during contraction and relaxation, circumferences of the forarm, thigh and calf on the both sides, breadth measures of the trunk (biacromial, bicristal and bitrochanteric dimensions), chest breadth and depth, circumference of the chest at rest, inspiration and expiration, breadth of the wrist and femoral condyles. The lack of differences in circumferential measures by diffe-



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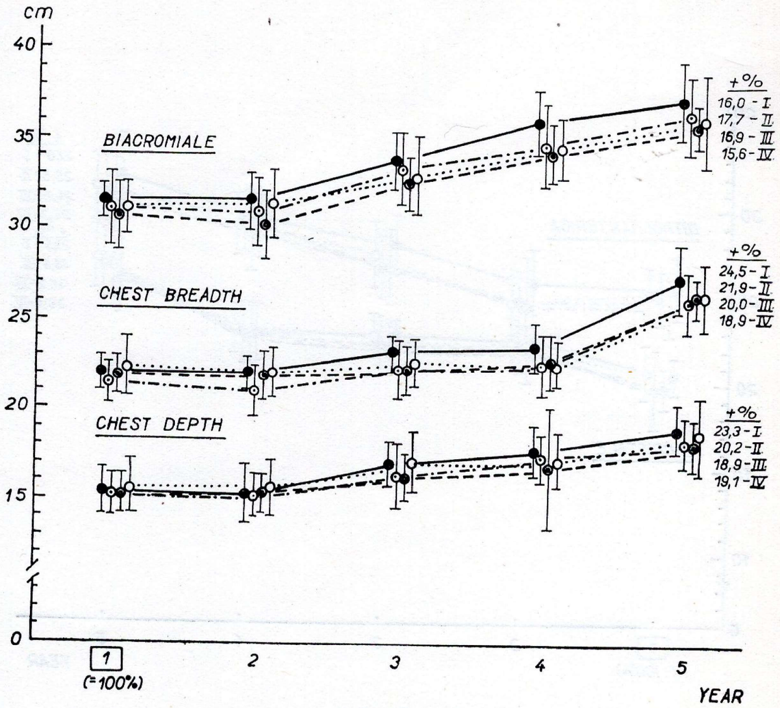

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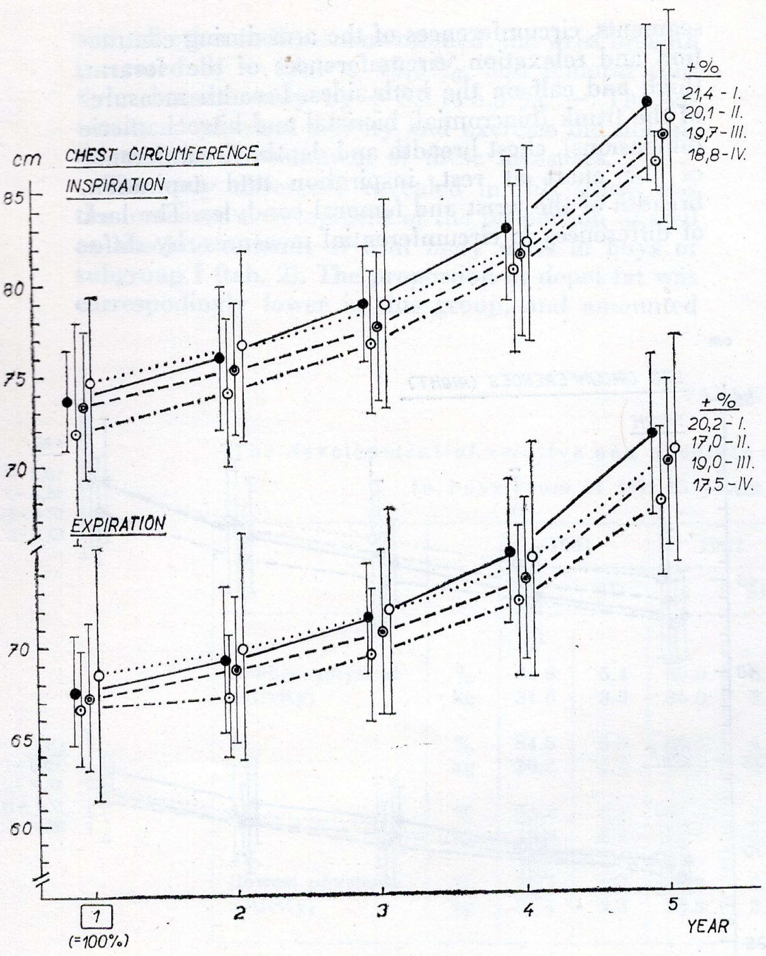

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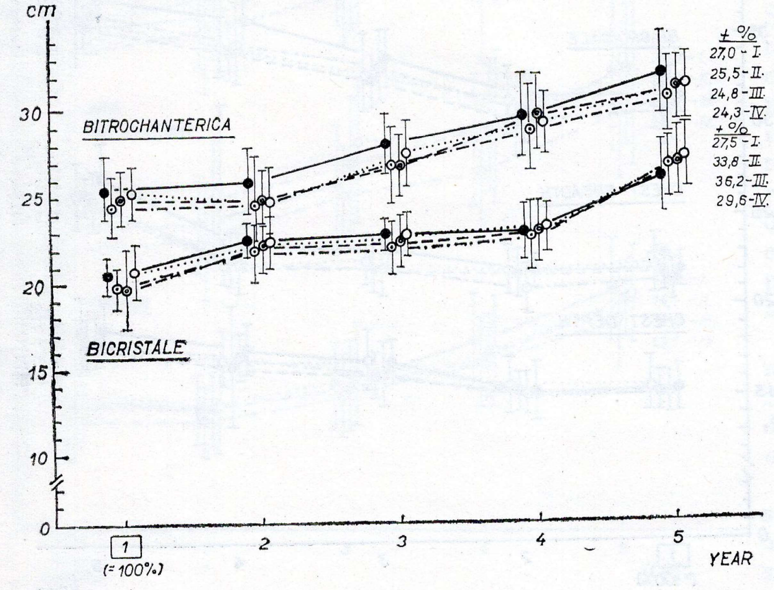

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segments, circumferences of the arm during contraction and relaxation, circumferences of the forarm, thigh and calf on the both sides, breadth measures of the trunk (biacromial, bicristal and bitrochanteric dimensions), chest breadth and depth, circumference of the chest at rest, inspiration and expiration, breadth of the wrist and femoral condyles. The lack of differences in circumferential measures by different development of body composition i.e. increased development of lean body mass at the expense of fat was elucidated: hypertrophy of the muscles in the extremities was compensated by decreased layer of fat. These indicators are therefore not reliable enough for the characteristic of physical fitness.

Detailed analysis of relative changes of individual anthropometric measures enabled the evaluation of relative increases and trends in different dimensions. Most remarkable were total body mass changes, especially of lean body mass and total body weight; then breadth measures of the pelvis increased relatively most. Length and circumferential measures increased relatively less (especially in distal segments), and least changes occured with breadth measures of the wrist and femoral condyles. which remained nearly the same at the age of 15 as in the age of 11. — The trend of the changes is not the same in all years — some indicators increased linearly (sitting height, leg circumference) most of them changed least from 11 to 12 years (weight, iliospinale — tibiale, arm circumferences, chest breadth and circumferences) and most from 14 to 15 years.

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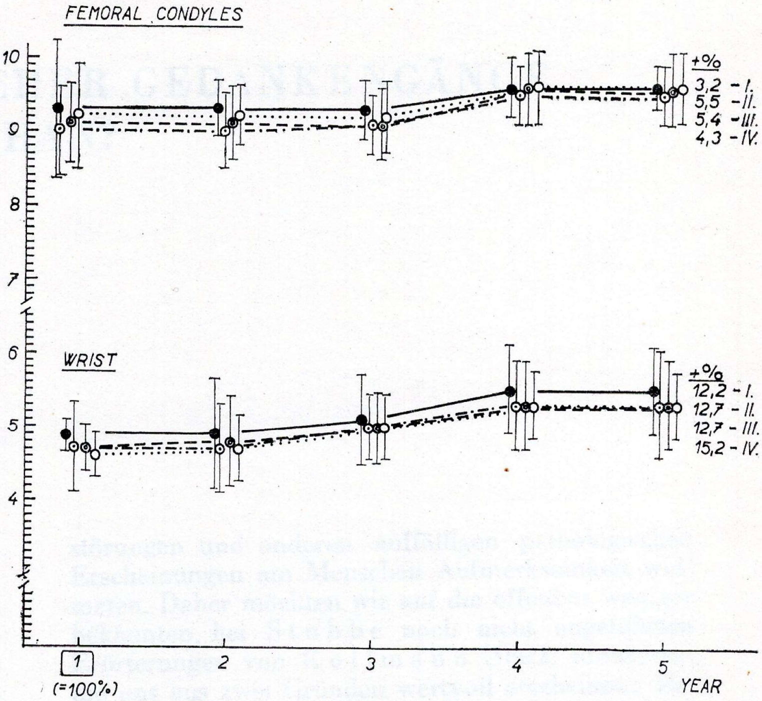

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