AN ANTHROPOMETRIC STUDY APPLIED TO BODY-BUILDERS

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The use of new, objective methods of investigation — hydrostatic weighing and calliperometry — has shifted in the recent years the problem of body composition to a privileged place of interest in medical research and in other science disciplines of human biology.

Most of the investigations conducted until now were focused on the solution of the problem of body composition under extreme pathological conditions, especially in obesity, less commonly in malnutrition disorders whereas from the domain of physiological research, i.e. in healthy population, reports are quite scarce.

Welham and Behnke in 1942 investigated a group of sportsmen, and in an objective methodical approach they pointed to a high degree of physical fitness though according to tables of ideal height and weight for the corresponding age, their sportsmen were within the range usually characterizing obese individuals [18].

The above authors thus pointed to the necessity of applying more physiological-qualitative aspects permitting a functional evaluation of the actual status of the organism as regards its basic components.

The composition of the human body is a dynamic feature susceptible of substantial changes not only during the growth and evolution of the organism, but also in adult and advanced age. Such changes occur owing to genetic, developmental and regulative factors and according to the degree of physical activity and the mode of nutrition.

If gradual and rather permanent increments of body weight are recorded in adult subjects previously exhibiting optimal weight according to weight and age, unless a simultaneous increase in physical activity occurs, then all the increments are almost exclusively constituted by depot body fat. The reverse is true in subjects exhibiting considerable physical activity, such as manual workers, sportsmen, persons taking regular exercise etc., in whom a relative overweight may be due to an increased percentage of active body matter represented, first of all, by powerful musculature.

The methodical approach to the evaluation of these two morphologically and functionally substantially different components of the human organism and methods of investigating quantitative shifts between them have been elaborated in the light of recent advances by Keys and Brožek [3, 4, 10, 11]. By objective methods they have confirmed the view of French authors that in fact the proportion of depot fat represents an "élément variable" of the body weight, its variation range being between 1 and 40 or more per cent [10, 5].

Of greatest interest for routine field investigations concerning the two main components was the discovery by the afore-mentioned and other authors of a close correlation between over-all fat of the organism and subcutaneously stored fat: under physiological conditions, the latter represents a constant proportion of the over-all body fat [3, 1, 14].

By means of respective regression equations based on the values measured, one can determine the percentage of the over-all fat and, indirectly, also the amount of active body matter (proportions of the two main components of the body weight). A survey of body composition thus obtained affords at the same time a picture of functional fitness, the degree of training, performance capacity and actual status of nutrition.

Object, methods used, and mode of material evaluation

In our investigation we have applied the above knowledge to the end of studying the influence of a new form of physical culture — bodybuilding — on somatic development and on body composition.

Twenty six participants (two from Poland) of the all-Slovakian competition in bodybuilding, having taken place in December 1965, in Bratislava, were examined.

Our attention was focused in the first place on anthropometry, individual history of sports activities and nutrition, further on physical performance in the course of the competition.

The main somatic data, body height and body weight, were obtained according to standardized criteria of anthropometry, the age of each participant was stated as the data of examination.

Three values were recorded for breast circumference: breast circumference at the mean respiration position at the level of breast nipples, values at

maximum inspiration and maximum expiration. Circumference of both arms was recorded at maximum contraction of the biceps and triceps muscles.

Calliper measurements were carried out by one of the authors, using the callipers devised by Best [2], in the modification of Pařízková [13]. Twelve standard sites on the body surface were selected on the right; 10 were chosen in accordance with Pařízková, measurements in the neck site were according to Hejda [7]. In addition, we determined also the value over the biceps.

In computing the WH-index, the data of Budlovský and Grunt [6] were used as a reference base. To compute the percentage of body fat and active body matter the nomograms elaborated by Pařízková [16] were utilized.

By means of a dynamometer the force of hand clasp was measured on three consecutice occasions on both sides. Further, as functional tests, the sport performances attained in the competition were evaluated: weight lifting at biceps contraction (weight bar grasped with palms up), in bench press and in squatting with weight bar on the chest.

On analysing statistically the data obtained, special attention was paid to establishing respective correlations or regression relationships between individual indices of somatic and functional development.

Characteristics of the group

The number of participants, n = 26, the mean age of the bodybuilders was 21 years (the youngest was 18 years old, the oldest 27). No acute intercurrent or chronic affection was found by medical examination of the participants before the opening of the competition, and the health condition in all was assessed as very good. The bodybuilders practised the sport for an average of 2.7 years (minimum 1 year, maximum 5 years), performing exercises five days a week on an average (minimum 3 days, maximum 7 days); the mean duration of a training was 1,8 hours (minimum 1 hour, maximum 2.5 hours). The structure according to profession was as follows: 57 per cent — university students, 43 per cent employees of whom 31 per cent performed light work, 12 per cent were manual workers.

RESULTS

The mean body weight of the participants was 76.0 kg (variation from 59.0 kg to 89.0 kg), the mean body height was 175 cm (162—185 cm).

The mean value of the group for body weight as expressed in the per cent of ideal weight according to Broca was 101 per cent (89—111 per cent).

The weight-height index (expressed in standard deviations, (mean +0.22, var. −0.09—0.42).

The sum of the width of ten skin folds: mean value was 58 mm (37—84 mm). The percentual proportion of body fat: mean value was 12.0 per cent (var. 8.0—15.5 per cent), of active body matter referred to body weight: mean value 88.0 per cent (var. 84.5—92.0 per cent).

TABLE 1

Mean Values for individual skinfolds measured in 12 body surface sites

Serial Number	Type of fold	Mean values in cm			
		Bodybuilders n = 26, age = 18—27		Hejda, age 18—25	Difference
		$\bar{x}$	s_x	$\bar{x}$	
1	2	3	4	5	6
1.	Cheek	0.52	0.101	.	.
2.	Submental fold	0.38	0.116	0.70	0.32
3.	Chest I	0.46	0.139	1.20	0.74
4.	Upper arm	0.26	0.024	1.20	0.94
5.	Back	0.82	0.122	1.40	0.58
6.	Chest II	0.44	0.122	1.10	0.66
7.	Flank	0.34	0.092	1.10	0.76
8.	Abdomen	0.58	0.213	1.30	0.72
9.	Thigh over patella	0.62	0.134	0.80	0.18
10.	Calf	0.45	0.186	1.20	0.75
11.	Neck	0.94	0.176	1.30	0.36
12.	Biceps	0.38	0.090	.	.
13.	Sum of ten skinfolds (1—10)	5.80	1,086	.	.

The mean density of the group was 1.068 g/ml (var. 1.060—1.079 g/ml).

The mean values for breast circumference — resting value 107.0 cm, minimal 100.0 cm, maximal 114.0 cm. Circumference of the right arm: maximal triceps = 35.65 cm (variation range 32—41 cm), maximal biceps = 39.23 cm (variation range 35—47 cm). Left extremity: maximal triceps = 35.17 cm (var. r. 31—40 cm), maximal biceps = 38.35 cm (var. r. 35—44 cm).

The data on the distribution and amount of subcutaneous fat, as compared with the values obtained by Hejda in Czech men, are presented in the Table 1.

Diagram 1 shows the regression relationship between the weight-height index and the percentage of over-all body fat and the respective correlation coefficient obtained.

Diagram 2 illustrates the group as regards body weight, height, and chest circumference. By means of it the mean body weight corresponding to a given height and mean chest circumference may be readily read. This connection-line nomogram was plotted on the basis of numeric expression of a multiple regression equation that expresses the relation between body weight and body height on the one hand and the mean chest circumference on the other. The equation reads:

$$y = -78.415 + 0.564\,x_1 + 0.522\,x_2$$

in which y = body weight
x_1 = body height
x_2 = mean chest circumference

To see the reliability interval of body weight values computed from the above equation we established also the corresponding standard deviation: $s_{y.x_1x_2} = 3.604$.

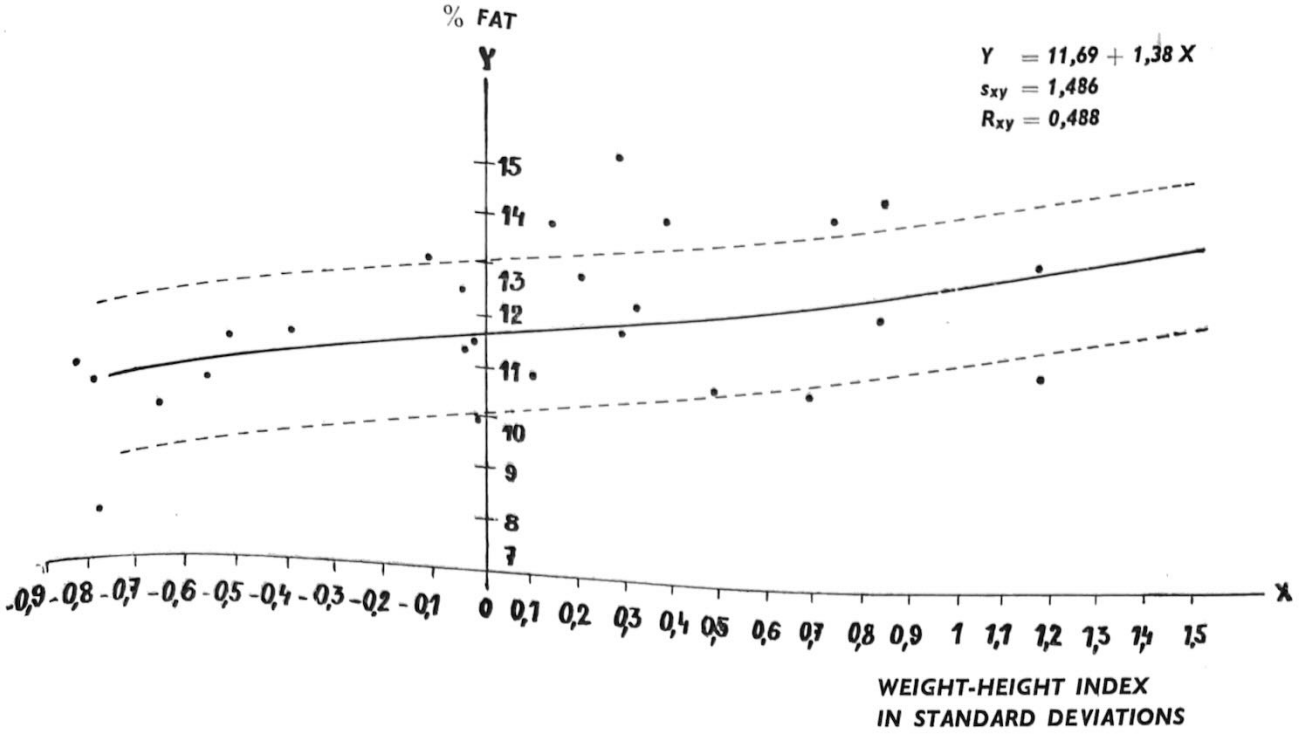

DIAGRAM 1.

Relation between the weight-height index and the percentage of the over-all fat in selected sportsmen.

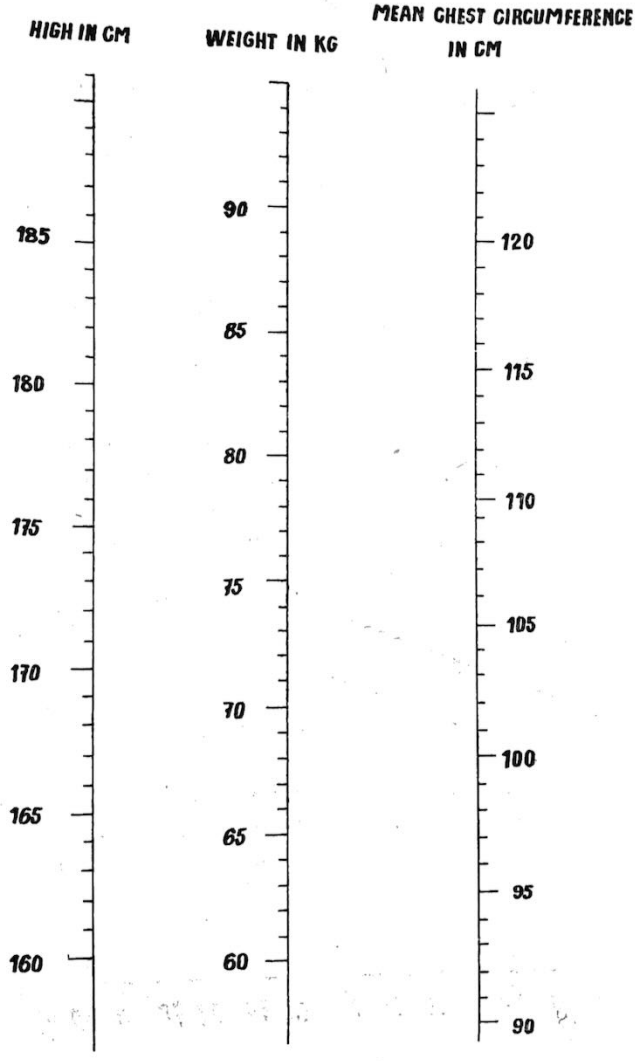

DIAGRAM 2.

Relation between body weight, height and mean chest circumference in selected sportsmen

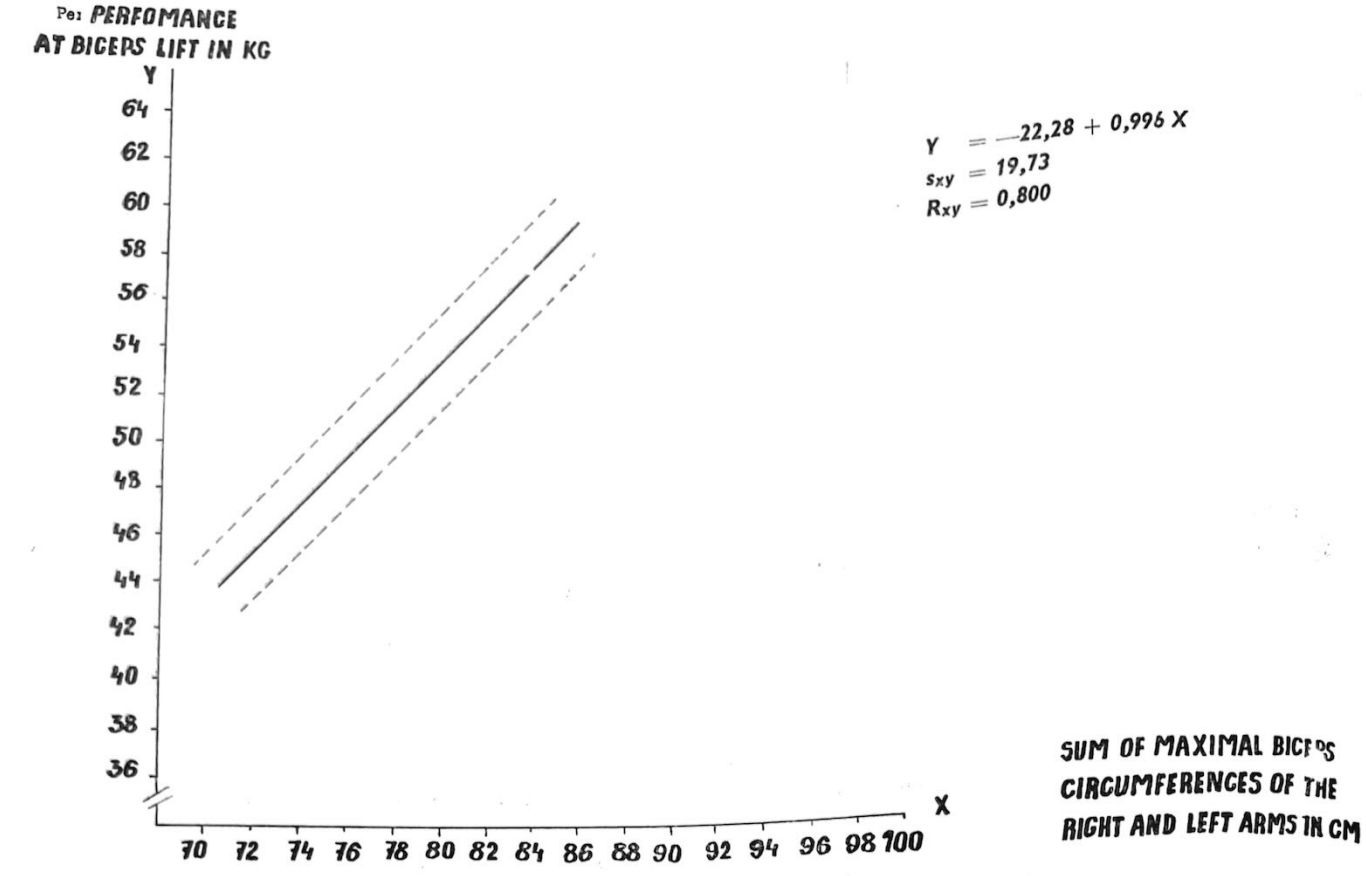

DIAGRAM 3.
Relation between the sum of maximal biceps circumference of the right and left arms and the biceps lift performance.

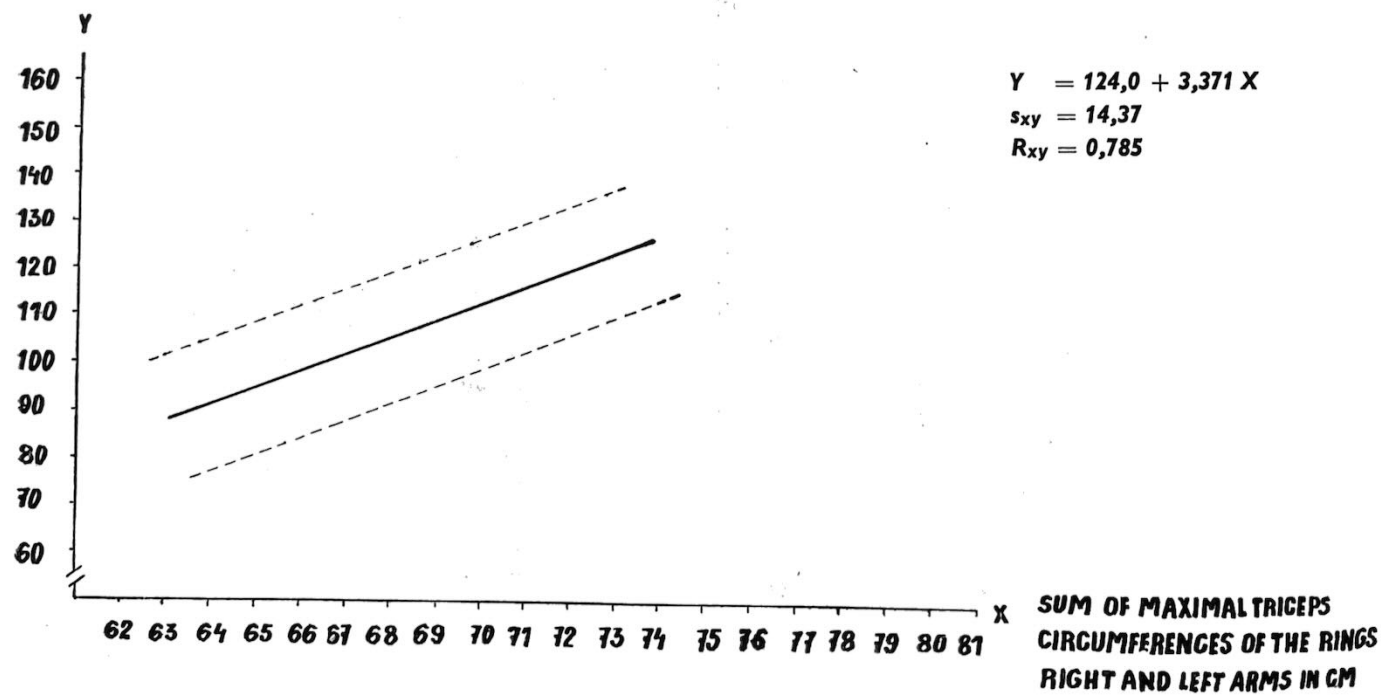

DIAGRAM 4.
Relation between the sum of maximal triceps circumference of the right and left arms bench-press.

The closeness of correlation between the three somatic parameters is shown by the respective correlation coefficient, partial correlation coefficients as well as by multiple correlation coefficients. Their values are given in Table 2. The simple and multiple coefficients of correlation proved to be statistically significant, P being 0.001, for partial correlation coefficients of correlation, P 0.01.

TABLE 2

Values of correlation coeficient between individual somatic parameters

Serial No.	Coeficient of correlation between	Values of corellation coeficient
1	2	3
1.	Body weight and height r_{yx_1}	0.788
2.	Body weight and mean chest circumference r_{yx_2}	0.796
3.	Body weight and height with exclusion of the effect of the mean chest circumference $r_{yx_1.x_2}$	0.589
4.	Body weight and mean chest circumference with exclusion of the effect of body height $r_{yx_2.x_1}$	0.608
5.	Body weight, height and mean chest circumference $R_{y.x_1x_2}$	0.872

The results of function tests are expressed in terms of the force of the right hand clasp — mean: 79.0 kg (minimum 59.0 kg, maximum 100.0 kg), the left hand clasp — mean 70.0 kg (minimum 50.0 kg, maximum 100.0 kg). The sport performances during the competition were as follows: mean biceps lift 55.0 kg (minimum 42.0 kg, maximum 65.0 kg), mean performance at bench-press — 115.0 kg (minimum 87.0 kg, maximum 160.0 kg), mean performance in squat — 115.7 kg (minimum 87.5 kg, maximum 152.5 kg).

In further investigations an attempt was made to verify the reliability of arm circumference at maximum biceps or triceps contraction as a measure of functional capacity.

To this end we investigated the correlation between the performance at maximum biceps contraction and maximum biceps circumferences. The resulting correlation coefficient is r = 0.800; the respective straight line of regression is presented in Diagram 3. In the same way correlation was established between bench-press and maximum triceps circumference. The correlation coefficient is r = = 0.785, the respective straight line of regression is reproduced in Diagram 4.

By computing the correlation coefficients it was proved that the quantitative anthropometric index of arm circumference is a reliable clue for functional evaluation of the performance capacity of the organism.

By taking the individual nutritional history it was shown that 59 per cent of the group were accustomed to take the main midday meal in collective self-services, the rest individually taking their meals in families, without paying any respect to increased energy output in days of training except for milk whose consumption amounts to 1.5 l a day per subject in the group (minimum 0.5 l, maximum 2 l a day).

The mean number of meals taken was 4 meals in the course of the day (minimum 2 meals, maximum 6 meals).

Additional food allowances consumed were recorded especially in university students, in the first place milk (with few exceptions bought almost daily), pastry (ordinary or sweet), yoghurt — 3 times in a week, meat products, eggs, butter, cheeses, curd, twice a week on an average; cream and fruit preserves were bought less frequently.

In spite of the critical period of nutrition, we did not record in a single case additional intake of fresh vegetables and fruit, not even of refrigerated products or southern fruits. Especially in university students, this circumstance was under the influence of economic aspects of food consumption.

DISCUSSION

While nutritionists evaluating the nutritional health status of various populations and social groups may be satisfied with comparing the data on body weight and height with corresponding standard values for a given population, these criteria are insufficient in evaluating sportsmen or in more detailed anthropological studies.

In a previous work, one of the authors, using the same basis of comparison for the evaluation of weight-height indices as applied in the present study, established in the so-called healthy population of 25—40-year-old males a statistically highly significant correlation between the weight-height index and the percentage of body fat, expressed by a correlation coefficient of 0.792 [9].

In our group we found that an analogous correlation shows but a medium closeness expressed by the coefficient of correlation, r = 0.4884. That denotes that the weight-height index is no more reliable owing to the changes that have occurred in the body composition of sportsmen.

The effect of sport on the organism is reflected in mutual shifts between fat-free body matter and fat. It is therefore necessary, in order to evaluate exactly the actual status of the sportsman's organism, to complete current anthropometric measurements — body weight, height and their relation —

with the establishment of one of the above components; thereby also, in an indirect way, an insight into the other component is gained.

In the first place, in sportsmen as in manual workers one may presume a greater share of active body matter as a result of well-developed musculature, in the comparison of the corresponding age group of average population.

Our results attest to the fact that the absolute values of subcutaneous tissue as measured with callipers are lower in sportsmen in comparison with those of clinically healthy population of males of the same age, as pointed out in Table 1.

Hejda [11], in his group, stated the mean width of skin fold, as measured in 12 sites, to be 1.20 m for males up to 40 years of age; similar average value in our group, though obtained in not completely identical sites, exhibits not even a half of the above value (0.52).

Keys and Brožek established the standard share of the over-all body fat to be 14 per cent of the body weight and density 1.0629 [10] for an average 25-year-old man of American population.

Pařízková confirmed the fact that the fat content in similar physiological groups of our population is practically identical so that the above figures may be considered at the same time as the norm for the population of this country [15].

Petrásek and co-workers, using the hydrostatic method of weighing, found in 15—20-year-old males of Prague population, of normal weight with respect to height, the proportion of fat to be 19.4 per cent and the density, 1.049; for the age-group of 21—30 years, the values were 23.4 per cent and 1.040 respectively [17].

The group of bodybuilders studied shows an average of 101 per cent of ideal weight, but the proportion of body fat shows the mean value of 12.0 per cent, the standard deviation being 1.676; in comparison with the values referred to above these figures are considerably lower. The corresponding higher mean density of 1.068 g/ml only underlines the greater share of active body matter at the normal weight of the bodybuilders. In this respect, certainly an important part is played by regular physical activity — training five times a week, lasting 1.8 hours.

However, regular physical activity represents only one of the main factors influencing the development of the organism and its composition, the other is the mode of nutrition.

Hejda and Fábry found increased amounts of subcutaneous fat in people showing a less frequent food intake [8].

The dietary regimen of the bodybuilders is characterized by an average of four meals a day consisting of mixed food, further by the above-average milk consumption of 1.5 l per person and day as compared with the recommended allowances for the average consumer. They showed also preferential additional consumption of animal proteins, keeping low glycides, i.e. favouring consumption of biologically valuable food. One may, therefore, presume that the body composition of the body (muscle) builders had been favourable influenced by the described mode of nutrition.

The quantity and proportion of active body matter with respect to the over-all body weight may serve as a criterion for physical fitness and resistance, the degree of training attained, working capacity and ability (quoted from Pařízková, p. 30, ref. 16).

If we compare our results of the function test of mean force of hand clasp with the values obtained by Novotný and Titlbachová [12] in participants of European Boxing Championship, we find substantial differences in the mean values as well as in maximum performance. In boxers, the above authors described the mean force of the right hand grasp to be 45 kg (var. 29 kg to 75 kg) and of left hand grasp, 44 kg (var. 29 kg — 71 kg). The above authors investigated 10 competing weight categories and they point out that the mean force of hand grasp rose in the function of body weight categories.

As regards weight variations, the group studied by us was more homogeneous so that the resulting mean values were not influenced to such a degree by lower weight categories; even so the difference between the two performances in the two groups is pronounced. In bodybuilders the force of the hand clasp for both hands was 100 kg, whereas this performance was not reached even by the highest weight category of boxers.

The important degree of training fitness and physical performance capacity in bodybuilders is reflected also in further sports performances. They correlate well with quantitative anthropometric data (circumference values) related to the largest measure to powerfull musculature, less to the skeleton, and, up to a negligible degree, to subcutaneous fat.

In sportsmen with low subcutaneous fat values, circumference measures represent, at the same time, valuable indicators of the physical performance capacity.

From the above aspect, the new form of physical education — bodybuilding (musclebuilding) may be considered as beneficial, first of all with respects to the degree of physical fitness and the performance capacity attained, and it may be looked upon as an important factor in the prevention of obesity. This would apply especially to university youth, mostly exhibiting a relatively little physical activity.

SUMMARY

An anthropological study was undertaken in 26 participants of an all-Slovakia competition in bodybuilding.

The investigation was focused on the relationship between the individual quantitative and qualitative somatic indices and the degree of functional capacity.

A connection-line-nomogram has been presented for the determination of body weight with regard to body height and resting chest circumference in active sportsmen.

Using calliperometry and the established relation

of calliperometry to hydrostatic weighing, the percentage of body fat is computed from the sum of 10 skin folds. By comparing the data obtained with standard values, new possibilities are offered for the diagnosis of early, mostly latent obesity as well as for an indirect assessment of the share of active body matter and hence also the degree of functional development attained.

Attention is drawn to the inadequateness of the application of current — quantitative indicators in evaluating the somatic status of sportsmen.

Qualitative aspects and the favourable effects of the nutritional regimen of bodybuilders are pointed to, as well.

To conclude, the significance of the new sport discipline — bodybuilding (musclebuilding) — is described as an effective factor for attaining a high degree of physical fitness and performance capacity. Also, its importance for the prevention of obesity is stressed.

LITERATURE

1. ALLEN T. H., PENG M. T., CHEN K. B., HUANG T. F., CHANG C., FANG H. S.: *Metabolism 5, 346, 1956.*
2. BEST W. R.: *J. Lab. clin. Med. 43, 967, 1954.*
3. BROŽEK J., KEYS A.: *Brit. J. Nutr, 5, 194, 1951.*
4. BROŽEK J., KEYS A.: *Science 116, 140, 1952.*
5. BROŽEK J.: *Fed. Proc. 11, 784, 1952.*
6. BUDLOVSKÝ J., GRUNT J.: Príspevky k otázkam výživy a gastroenterológie. *Collective papers of the Institute of Nutrition Research, s. 150. SAV, Bratislava 1958.*
7. HEJDA S.: *Vnitř. lék. 7/7, 773, 1961.*
8. HEJDA S., FABRY P.: *Nutr. Dieta 6, 216, 1964.*
9. KAJABA I.: Dissertation treatise, I. diel, s. 107. *Lékařská fakulta hygienická Karlovej Univerzity Prague 1965.*
10. KEYS A., BROŽEK J.: *Physiological Reviews 33, 245, 1953.*
11. KEYS A., ANDERSON J. T., BROŽEK J.: *Metabolism 4, 427, 1955.*
12. NOVOTNÝ V., TITLBACHOVÁ S.: *Teorie a praxe tělesné výchovy a sportu 6/1, 16, 1958.*
13. PAŘÍZKOVÁ J.: Dissertation treatise. *VÚTL, Prague 1960.*
14. PAŘÍZKOVÁ J., KOLDOVSKÝ O., PÍPAL M.: *Československá hygiena 5/7, 405, 1960.*
15. PAŘÍZKOVÁ J.: *Vnitřní lékařství 7/7, 766, 1961.*
16. PAŘÍZKOVÁ J.: Rozvoj aktivní hmoty a tuku u dětí a mládeže. *SZdN, Prague 1962, s. 65. Thomayerova sbírka, sv. 413.*
17. PETRÁSEK R., RATH R., MAŠEK J.: *Review of Czechoslovak Medicine 11/4, 251, 1965.*
18. WELHAM W. C., BEHNKE A. R.: *J. Amer. Ass. med. 118, 498, 1942.*