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RELATIONSHIP BETWEEN SOME ANTHROPOMETRIC MEASUREMENTS AND BODY COMPOSITION IN INDIVIDUALS WITH DISSIMILAR PHYSICAL ACTIVITY

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The determination of the body composition in man has become an integral part in recent research on human biology. The approach to these prolems has been somehow restricted by current methodical facilities as only indirect measurements can be applied to the living organism in order to gain information on physical, physiological and biochemical processes. Results gained from animal experiments can be applied to human beings only to a limited extent because of the difference in biological and ecological factors. Laboratories engaged in this kind of research have to consider economical factors as well, because the equipment necessary for these estimations is very expensive and one single measurement takes up considerable time. These methods therefore cannot be employed for estimations in large groups of people.

The question has therefore been raised very frequently whether basic anthropometric measurements (height, weight, body surface etc) can supply a notion on the body composition and can provide a concept on the mutual relationship of the various body components. Most authors have performed studies on samples from an average population e.g. individuals in whom not one single basic component participating in the body composition has been prevalent (Behnke 1953, Best 1953, Ryan 1957, Edwards 1959, Von Döbeln 1959, Doolan 1962, Picon-Réategui 1962, Katch 1968, Michael 1968, Wilmore 1969).

Talbot (1938) made his measurements on obese subjects and defines obesity as a prevalence of abundant body fat over the muscle mass. There might be disproportions in these two body components in people showing an average body weight, whereas people with an overweight possessing bulky muscles need not necessarily be obese.

Our current study is concerned with the relationship of basic anthropometric estimations (body weight, height and body surface) and circumferences of limbs to body composition in people with a heterogenous physical activity, and owing to the dissimilarity of their physical efficiency each component of their lean body mass especially their skeletal muscles differs too.

THE SAMPLE STUDIED

Measurements were carried out on two sets of healthy males aged 18 to 31. The development of their muscle mass as well as their physical efficiency varied significantly.

The group of untrained subjects (N) consists of 30 men aged 18 to 27 ($\bar{x} = 21,1$) who did not take part in any sports activities. They performed exercices of a medium intensity for 90 minutes twice a week. Otherwise these people lead a sedentary life.

The second group consists of 25 top athlets, weight-lifters, competitors in all weight categories aged 18 to 31 ($\bar{x} = 22,9$). These sportsmen are training 6 days a week at maximal loads. All 25 belong to one complete training unit of top-trained sportsmen in their respective categories. By the selection of these samples we aimed at achieving the highest possible conformity of their motor activity within each group.

METHOD

1. Anthropometric estimations: Measurements of body height, body weight and circumferences of the arm, forearm, thigh and calf were taken (Fetter 1967). These estimations were measured on the right side of the body. From the body height and body weight, the body surface was calculated according to the formula of Du Bois-Meek:

$$M^2 = W^{0,425} \times H^{0,775} \times 71,84$$

M^2 — body surface, W — body weight, H — body height.

2. The lean body mass (LBM) was stated from the body density gained by hydrostatic weightings. The % body fat was calculated from the body density according to the equation of Keys and Brožek:

$$\% \text{ body fat} = \frac{4,201}{\text{body density}} - 3,813$$

The percentage of the LBM, the weight of the body fat and the LBM in kg were calculated out of the percentage of body fat.

3. The muscle mass was stated from the creatinine excreted by the urine per 24 h. This assessment of the muscle mass is based on the assumption that most of the creatine, the precursor of creatinine, is comprised in the muscles (98 %) and this amount corresponds to the muscle mass (F o l i n 1904, 1905, H u n t e r 1928, B o r s o o k 1947). For converting creatinine into 1 kg of muscle mass we used the coefficient of T a l b o t (1938), according to this coefficient 1 g of creatinine excreted corresponds to 17,9 kg of the muscle mass. It must however be realised that this coefficient has been derived empirically. According to C h e e k (1968) 1g of creatinine corresponds to 20 kg of the muscle mass. Using mean values of excreted creatinine would therefore be more appropriate. We preferred the calculations mentioned above because they are more instructive.

We are quite aware that this method for the assessment of the muscle mass is not ideal for the variability of the creatinine excreted. This method however is at present the most accessible for the work on healthy individuals and inspite of its shortcomings valuable informations on the development of the muscle mass can be gained.

4. Statistics (R o t h 1962, R e i s e n a u e r 1965): All basic statistical characteristics (arithmetical means, standard deviations and range) were first of all calculated. The t-ratio was used to determine significant differences between the two groups. Furthermore the correlation coefficient between the anthropometric estimations and the LBM as well as the muscle mass had to be calculated. Z-transformations were used for the significance of differences between each correlation coefficient.

95% was considered as confidence limit in all cases and is considered as sufficient in all biological observations. (The significance above the 95% limit is indicated by brackets with one line, the significance above the 99% limit by brackets with two lines in our tables.)

RESULTS

Table 1 gives the basic statistical data of different items.

B o d y w e i g h t: the mean body weight in group N amounted to 70,39 kg, in group V to 78,11 kg. In spite of the large difference between these two figures the statistical significance has been proved only up to the 95% confidence limit. This small significance of difference between average values was caused by a large range of figures in group V. This set included competitors in very low and very high weight categories. (Fig. 1)

B o d y h e i g h t : the mean body height in group N amounts to 176,28 cm, in group V to 170,96 cm. The difference is highly significant $p < 0,01$. (Fig. 1).

B o d y s u r f a c e : mean values of body surface in group N were 1,86 sq. m., in group V 1,89 sq. m.

TAB. 1
Basic statistical data on measurements in both groups
(Untrained subjects n = 30, weight-lifters n = 25)

Variable	Untrained				Weight-lifters			
	$\bar{x}$	min max	s	m	$\bar{x}$	min max	s	m
Weight kg	70,39	55,9 86,3	8,22	1,50	78,11	57,1 135,0	16,44	3,29
Height cm	176,28	167,0 189,0	6,57	1,20	170,96	158,0 183,0	6,72	1,34
Body surface m^2	1,86	1,6 2,1	0,14	0,02	1,89	1,6 2,5	0,21	0,04
LBM kg	62,64	52,3 81,7	7,10	1,30	68,34	51,5 106,1	11,86	2,37
Body fat kg	7,73	2,8 16,2	3,60	0,66	9,75	2,7 28,9	5,69	1,14
Muscle mass kg	30,07	18,1 42,3	6,61	1,21	37,91	26,8 57,1	8,06	1,61
Circumferences:								
arm cm	28,75	24,8 35,0	2,50	0,46	33,02	28,1 41,9	3,29	0,66
forearm cm	27,26	25,1 30,6	1,36	0,25	29,60	27,2 35,9	2,01	0,40
thigh cm	55,86	49,0 62,0	3,58	0,65	59,14	50,0 76,0	5,72	1,14
calf cm	37,40	27,0 49,0	4,20	0,77	38,65	34,2 47,3	2,84	0,57

The difference is not significant, values are almost identical. (Fig. 1)

LBM in kg: mean values found for group N amounted to 62,64 kg and for group V to 68,34 kg. The difference is significant $p < 0{,}05$. (Fig. 2)

Body fat in kg: mean values for group N were 7,73 kg, for group V 9,75 kg. The difference is not significant. (Fig. 2)

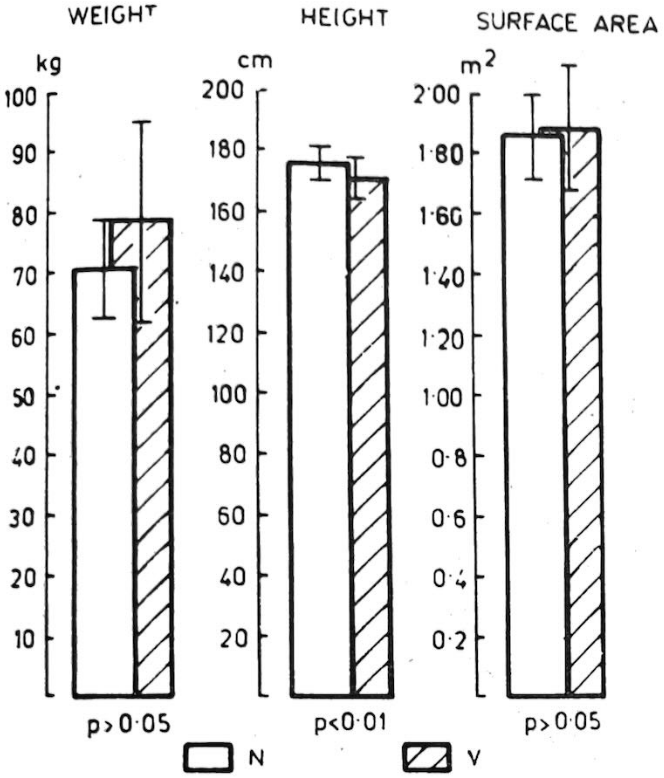

FIG. 1
Body weight, height and body surface

Muscle mass in kg: the mean muscle mass for group N amounted to 30,07 kg, for group V to 37,91 kg. This difference was highly significant $p < 0{,}01$. (Fig. 2)

Circumference of arm: mean values for group N were 28,75 cm, for group V 33,02 cm. The difference was highly significant $p < 0{,}01$. (Fig. 3)

Circumference of forearm: mean values for group N were 27,26 cm, for group V 29,60 cm. The difference was highly significant $p < 0{,}01$. (Fig. 3)

Circumference of thigh: mean values found in group N were 55,86 cm, in group V 59,14 cm. The difference is significant $p < 0{,}05$. (Fig. 3)

Circumference of calf: mean values in group N were 37,40 cm, in group V 38,65 cm. The difference is not significant. (Fig. 3)

CORRELATION ANALYSIS

Table 2 gives correlation coefficients calculated for the set of untrained individuals (N) and for the set of weight-lifters (V). The levels of significance for each correlation coefficient are indicated by^{xx} for $p < 0{,}01$ and by x for $p < 0{,}05$ %. (The range of significance between the correlation coefficients gained by z-transformation has been marked for both groups as indicated in the methodical part of the study.)

Weight: there is a very close relation between the LBM and the total body weight in both our

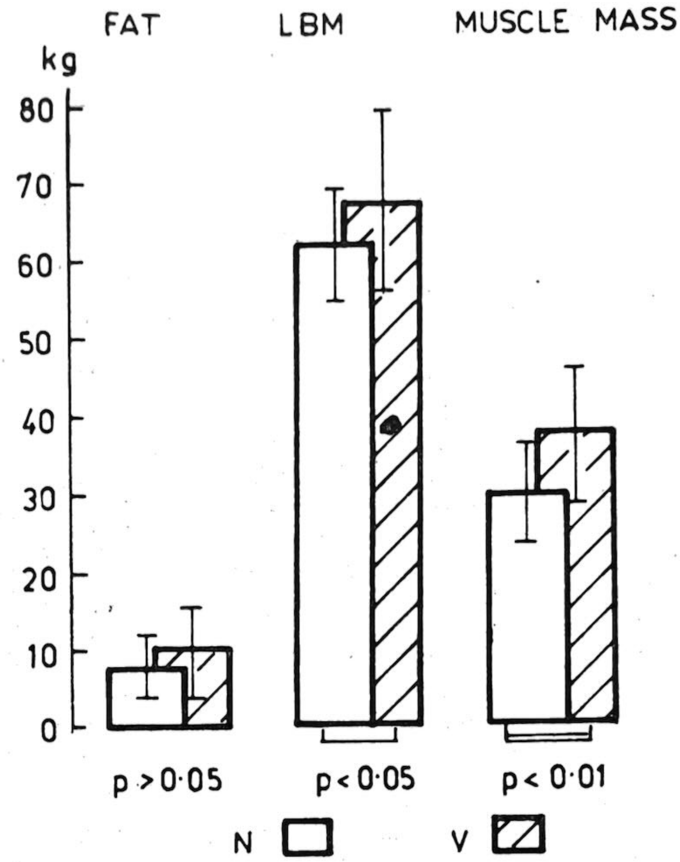

FIG. 2
Components of the total body weight

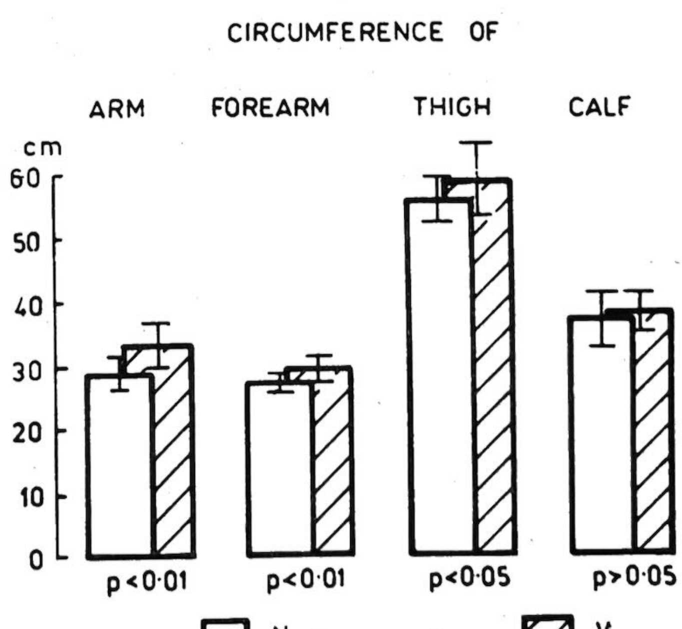

FIG. 3
Circumferences of single parts of the limbs

sets. For the set N was r = 0,90, for group V we found a correlation coefficient of r = 0,97. (Fig. 4)

For the correlation of total body weight and muscle mass we found a coefficient of r = 0,65, for group N and r = 0,67 for group V.

TAB. 2

Correlation coefficients

(Untrained subjects n = 30, weight-lifters n = 25)

Variable	Muscle mass		LBM	
	Untra-ined	Weight-lifters	Untra-ined	Weight-lifters
Weight	0,66××	0,67××	0,90××	0,97××
Height	0,48××	0,55××	0,63××	0,83××
Body surface	0,64××	0,67××	0,87××	0,96××
Circumference:				
Arm	0,57××	0,66××	0,55××	0,87××
Forearm	0,54××	0,73××	0,65××	0,93××
Thigh	0,59××	0,68××	0,74××	0,95××
Calf	0,39×	0,62××	0,31	0,88××

× $p < 0,05$
×× $p < 0,01$

H e i g h t : the coefficient for the correlation of body height and the LMB amounted to r = 0,63 for group N and r = 0,83 for group V. The relation of body height and muscle mass is less close, though still significant r = 0,48 for group N, r = = 0,55 for group V.

B o d y s u r f a c e : there is still a very close correlation between the body surface and the LBM; for group N r = 0,87, for group V r = 0,96. (Fig. 5)

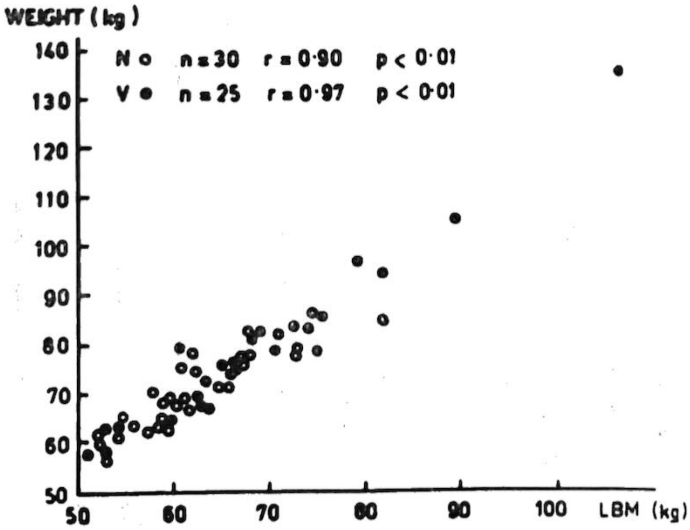

FIG. 4

Relation between the total body weight and the LBM

Correlation coefficients between the body surface and the muscle mass are somehow smaller, for group N r = 0,64, for group V r = 0,67.

The range of the coefficient found for the correlation of basic anthropometric estimations, the LBM and the muscle mass were calculated by z-transformations; we consequently established:

1. The correlation of body weight, height and the LBM is equally significant in both groups, the correlation of the body surface and the LBM differs above the 5% limit.

2. The correlation of body height, weight, body surface and muscle mass is equally significant in both sets.

3. There are significant differences between the correlations of body weight, body surface and the LBM as well as between correlations of body weight, body surface and the muscle mass in group N.

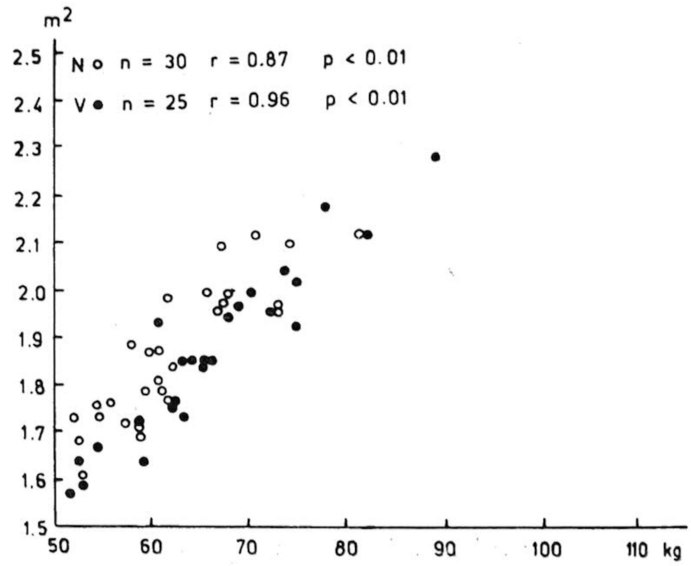

FIG. 5

Relation between the body surface and the LBM

4. Highly significant are the differences between the correlation of weight, body surface and the LMB as well as the correlation between body weight, body surface and the muscle mass in group V.

5. No significance could be established in the correlation between body height and the LBM as well as between the height and the muscle mass inside boths groups.

C i r c u m f e r e n c e o f a r m the coefficient for the correlation of the arm circumference and the LBM was found to be significant r = 0,55, just the same as for the correlation between the arm circumference and the muscle mass r = 0,57 for group N.

In group V the correlation coefficients were higher for the relation between the arm circumference and the LBM r = 0,87 as well as between the arm circumference and the muscle mass r = 0,66.

C i r c u m f e r e n c e o f f o r e a r m : the correlation coefficient between the circumference of the forearm and the LBM was significant for group

N r = 0,65. The same applies to the relation between the circumference of the forearm and the muscle mass r = 0,54.

Higher correlation coefficients were again found in group V. The correlation to the LBM was r = = 0,93 and the relation to the muscle mass r = = 0,73.

C i r c u m f e r e n c e o f t h i g h : a significant correlation coefficient was found for the relation between the thigh circumference and the LBM in group N r = 0,74 and for the relation to the muscle mass r = 0,59. (Fig. 6)

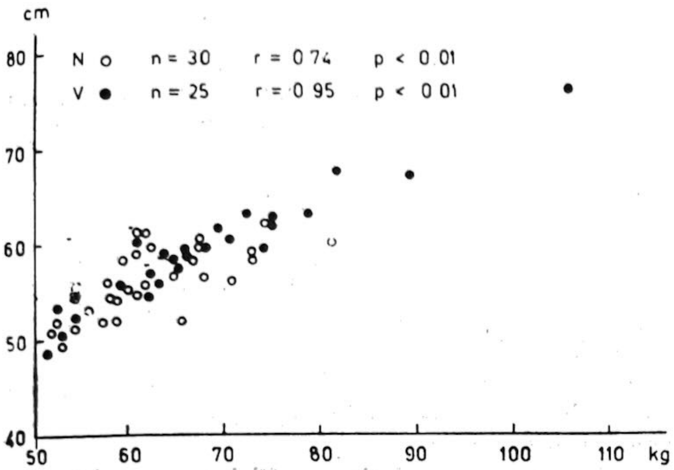

FIG. 6

Relation between the circumferences of the thigh and the LBM

A very close correlation of the thigh circumference and the LBM found in group V r = 0,95 and the same applies to the correlation of the muscle mass r = 0,68.

C i r c u m f e r e n c e o f c a l f : in examining the correlation of the calf circumference and the LBM in group N a very low insignificant correlation coefficient was established r = 0,31, the correlation of the calf circumference and the muscle mass was only slightly higher r = 0,39.

In group V the coefficients were however for the correlation between the calf circumference and the LBM r = 0,88 as well as the muscle mass r = 0,62.

Using z-transformations, we established:

1. The correlation of circumferences in each part of the limb and the LBM is always significantly closer in group V than in group N.

2. The correlation of limb circumferences and the LBM is always closer than the correlation to the muscle mass within the group V.

DISCUSSION

In both our sets we found close or even closer correlations between all our parameters, the muscle mass and foremost the development of the LBM. It must however be emphasized that our observations were performed on subjects in whom the body fat formed an average proportion of their body weight e.g. they were neither obese nor undernourished.

In these cases, according to our observations, the total body weight gives a satisfactory estimate of the LBM. As the proportion of fat which is the most variable part of the human body differs widely in individuals even within an average population, the weight of the individual gives only an approximate estimate of the LBM. It is difficult to state whether an increase in body weight is caused by an increase of one certain component in the LBM, and on the contrary whether a reduction in weight is caused by a decrease of body fat or the decrease of one definite component in the LBM e.g. the muscle mass.

Another question has been raised: to which extend the body weight might demonstrate the proportion of the muscle mass in the LBM. The relation between creatinine excreted, indicating the size of the muscle mass and the body weight has been demonstrated by our results as well as by studies published by other authors (R y a n 1957, P i c o n - R é a t e g u i 1962). Correlation coefficients in these cases are smaller than the relation of body weight and LBM, we have even discovered studies denying the existence of these correlations altogether (B e a r d 1932, P a r o t 1965). P i c o n - R é a t e g u i (1962) who found the correlation r = 0,72 stated that this correlation depends not only on the size of the LBM, but on the total amount of water in the organism as well as on the part played by the extracellular and the intracellular fluid of the body.

This correlation is evidently influenced by the different components participating in the LBM, the significance of their correlation is therefore essentially smaller than the significance in the correlation of body weight and the LBM proper. Various authors have published different views on these problems, the selection of subjects to be measured is therefore very important.

We established smaller correlation coefficients for the relationship between the body height and the LBM as well as the muscle mass; this observation again corresponds to investigations by other authors (P i c o n - R é a t e g u i 1962). A very close correlation (r = 0,94) between the LBM and the body height was found by Von D ö b e l n (1959). The body surface seems to be however more appropriate for estimations. Our observations of this item correspond to those by other authors too (B e h n k e 1953, R y a n 1957, E d w a r d s 1959, D o o l a n 1962, P i c o n - R é a t e g u i 1962).

We therefore conclude from our results that the estimation of an adequate LBM stated on the basis of body height and weight can only be made in subjects with an average development of body fat. The estimation of the muscle mass based on these anthropometric characteristics is more accurate in subjects whose muscle mass forms the bulkiest part of their LBM.

Circumferences of the extremities are somatic characteristics very often employed for the assessment of the muscle mass and very rightly as so considered that muscles participate with 36—42 % in the body weight. The share of muscles in the total muscle mass amounts to 56 % for the lower limb and about 28 % for the upper limb. The muscle mass of the extremities participates therefore with 84 % in the total weight of the skeletal muscles and approximately with 33 % in the total body weight.

Matiegka (1921) elaborated a method based on these facts using various circumferences of the extremities for calculations of the size of the muscle mass. Other authors have tried to improve the prediction of the LMB from skinfolds by using multiple regressions of skinfolds, circumferences and the LBM. (Durnin 1967. Katch 1968, Michael 1968, Wilmore 1969). We have however not been able to detect any studies on the relationship between circumferences and the size of the muscle mass. According to our results circumferences of the limb segments supply us with information on LBM in average young men. High values of correlation coefficients in the group of weight-lifters proved this information to be very good (Malkovská, in press). Very high correlations between circumferences of the thigh, the forearm and the LBM were found in the group of untrained subjects. In evaluating these relations we must necessarily realize that both groups were fairly homogeneous as regards the proportions of their body fat. Difficult to tell whether these correlations would be found in groups less homogeneous.

The relation between circumferences and the muscle mass is surprisingly less close than between circumferences and the LBM inspite of very bulky muscles particularily in weight-lifters. This difference can be explained by the fact that, in measuring circumferences of limbs, values gained include muscular tissue as well as bones, two very important morphological components of the LBM.

In all parameters measured we attained higher correlation coefficients for group V. Most probably the layers of fat tissue are negligible on the selected sites in weight-lifters while they are larger in untrained individuals. This supposition could however be proved only by measuring layers of subcutaneous fat. Such measurements cannot be carried out with a calliper as the skinfolds cannot be lifted and measured reliably on the selected sites. X rays of the limbs or measurements by ultrasound should be used for calculations of so called ideal mean values of the extremities bare of fat tissue. Even then we would be wrong considering the extremity to be of a cylindrical shape, additionally we have to take into account that the body fat is not evenly distributed round the whole circumference of the limb (Blažek 1967).

Relations between anthropometric parametres and the LBM as well as the muscle mass indicate that the body composition can be evaluated by this technique particularly in subjects with very bulky muscles. The precision of the prediction is however limited to a certain extent in average individuals this prediction can be improved by the combination with certain suitable parameters (Wilmore 1969). Apart from basic parametres especially circumferences of the extremities could be employed for these assessments. Anthropometric messurements are undoubtedly very useful as a complementary method for the determination of body composition, as our attention might be drawn to anatomical relations which might pass unnoticed when employing a different technique for the evaluation of body composition.

SUMMARY

This study deals with relations between certain anthropometric estimations and the lean body mass as well as the muscle mass in subjects with dissimilar physical activity. Measurements have been carried out in a group of 30 untrained men and in 25 top efficient weight-lifters between the age of 18 to 31.

The body weight, body height, body surface and circumferences of segments of the limbs have been determined. The LBM has been stated densimetrically and the muscle mass by the excretion of creatinine.

In comparing anthropometric estimations and the body composition between the two groups significant differences have been found especially for the circumferences of the limbs, for the lean body mass and the muscle mass. No significant differences between the two sets could be established for the amount of body fat.

Differences in correlation coefficients found for the relation between anthropometric parameters and the body composition were evaluated by z-transformations and we therefore established:

1. The relation between body weight, body surface and the LBM as well as the muscle mass is equally significant for both sets.

2. Significant are the differences between the correlations of body weight, body surface and the LBM as well as correlations of these parameters within the group of weight-lifters and within the group of untrained individuals.

3. Significant are the differences of relations between body height and the LBM as well as the muscle mass inside the group of weight-lifters.

4. Closer relations between each circumference and the LBM were found for the set of weight-lifters than for the group of untrained individuals.

5. A closer relation between anthropometric estimations and the LBM than between these estimations and the muscle mass has been found inside each groups.

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