

POSSIBILITIES FOR THE USE OF SELECTED METHODS FOR THE DETERMINATION OF BODY COMPOSITION IN CHILDREN IN THEIR ADOLESCENT STAGE

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The variables of fat mass (FM), fat free mass (FFM) and total body water (TBW) are considered to be the most important components of the body's composition. At present, there are quite many methods for the evaluation of body composition. They differ in both devices used and personnel requirements and in the determination accuracy of the monitored data, which are the most important factors limiting their use under various conditions. The aim of our work is to find out more details about those methods for the determination of body composition that are available at present and to consider their possibilities in use for a group of children under laboratory and field conditions. Altogether, the following subjects were tested, $n = 30$, aged 10 to 14 years, 17 of whom were boys and 13 of whom were girls. A good match, of the DEXA method and other chosen methods for the determination of body composition, was found in both boys and girls, but from the statistical and objective significance points of view, we deduce a considerable differentness between various methodics mainly due to the differentness of prediction equations.

Keywords: Body composition, components of body composition, methods for determination of body composition.

INTRODUCTION

Generally, we can divide the human body into several components that form mutual relations with each other (Wang et al., 1992, 19; Pařízková, 1998a, 1). The variables of fat mass (FM), fat free mass (FFM) and total body water (TBW) are considered to be the most important components of the body's composition. All of the components of the body's composition are subject to the impact of many external as well as internal factors. Body composition, commonly approached as a proportion of active mass and depot fat, creates an expressive somatic marker that is associated with specific developments, based on age, gender and level of physical condition. Therefore, the determination of the proportion of active mass and depot fat is not defined only by a certain morphological feature, but it also provides a basis for organism assessment from the point of view of its functions (Pařízková, 1962, 123). Epidemiologic studies show that not only the total amount of the body fat, but also its distribution, are important for the occurrence of cardiovascular diseases and type 2 diabetes. Central fat distribution is also connected with adverse effects on fitness characterized by hyperinsulinism, dyslipidemia and glucose intolerance, which mainly increase the risk of cardiovascular diseases (Chan et al., 2003, 445). Maffei et al. (2001, 179) mention in their study the relationship between waist circumference and the risk factors of cardiovascular diseases as follows: there is a negative correlation between the waist cir-

cumference and the HDL cholesterol level, the results of lipid spectrum examination and blood pressure values in preadolescent children significantly relate to the anthropometric indexes evaluating fat mass distribution; they also found a high degree of dependence between the waist circumference and skinfold thickness at the triceps and subscapular area. According to Teixeira et al. (2001, 434) the sum of 3 trunk skinfolds (the abdominal, subscapular and the suprailiacal skinfold) strongly correlated with the total amount of trunk fat (measured by DEXA method). The sum of three trunk skinfolds further strongly correlated with HDL cholesterol values, the proportion of total cholesterol/LDL cholesterol and with apolipoproteins A-I being independent of body thickness. At present, there are quite many methods for the evaluation of body composition. We can divide them into three basic groups: direct methods (level I), indirect standard laboratory (reference) methods (level II), and field methods (level III) (Bunc et al., 1998; Pařízková, 1998a, 3, 4; Malá et al., 2008). They differ in both devices used and personnel requirements and in the determination accuracy of the monitored data, which are the most important factors limiting their use under various conditions (Roche et al., 1996, 15). The availability of the methods presented as so-called "reference" methods, is limited in our situation due to their high technical and financial operating demands; these methods are virtually impracticable for field population studies. They are also known as "once indirect" methods and the most widely used method at present is dual energy X-ray absorp-

ciometry (DEXA). DEXA is considered to be a “gold standard”, its availability is, however, limited, due to its high financial operating demands, therefore it is mostly used for verification of derived methods (i.e. level III methods) the availability and operation of which are much less demanding. The underwater weighing method of body composition analysis used earlier is being used less at present due to its technical demands (Malá et al., 2008). Regarding field methodics (level III) that are readily available, less time consuming, as well as being technically and financially manageable but less exact, we can mention anthropometry in particular (stature and body weight, BMI, WHR, estimation of body composition based on skinfolds – caliperation...) and bioelectric impedance (BIA) (Brodie et al., 1999, 801; Pařízková, 1998a, 3; Bunc, 2001a, 103). BMI however does not reflect an exact proportion of fat and fat free mass. The amount of fat mass (%) increases with age and is higher in women than men, but these differences may not be involved in BMI (WHO, 1995). In comparison to BMI, the fat mass (%) has a greater predicative ability and is more tightly connected with the health hazards that arise from its amount and distribution in the body (Deurenberg et al., 1989, 624; Deurenberg-Yap et al., 2003, 81). However, the determination of body composition using the BIA method determining total body water (TBW) and its fractions (ICT, ECT) is also not “trouble free” (Lukaski et al., 1985, 810). It is necessary to emphasize that the amount of water in an organism depends on the individual’s age, weight and gender and that it individually varies according to intake and output (Heyward et al., 1996, 44).

Each of the measuring methods has its error sources that have to be taken into account. Aside from the financial and technical demands, there are also prediction equations that represent the major difficulty of the usability of the current methods for the determination of body composition. Unfortunately, there is no universal prediction equation that could be used for all of the population groups. Many of the equations either have been taken over from foreign studies or were formed more than 25 years ago. Therefore, it is necessary to update these equations and mainly to determine such prediction equations as would respect not only age and gender, but also the individual’s level of physical activity and individual variability in body composition. To minimize any error of all of the indirect methods for the determination of body composition, it is necessary to use specific prediction equations formed from a sample of the factors of age, gender, nationality, health condition and level of motion activity corresponding with the examined person (Deurenberg et al., 1989, 628; Baumgartner et al., 1990, 223). Since the fat mass distribution varies based on age, gender, motion activity, etc., the validity of regression equations for the estimation

of body composition from skinfolds is limited only to the population from which the equations were derived.

We can find a number of companies that offer an analysis of body composition by means of various methodics. Unfortunately, it has become a routine that the single methods are combined with each other and the results are often interchanged in spite of the fact that each of the methods is based on different principles and presumptions. Therefore, it is now necessary to consider the efficiency of individual methods for the determination of body composition as well as to solve the problem of the partial compatibility of these methods.

The aim of our work is to find out more details about those methods for the determination of body composition that are available at present and to consider their possibilities in use for a group of children under laboratory and field conditions. The partial aim was to find out about a suitable kind of laboratory equipment that would be available in our environment as well as abroad, and that would allow for not only a single analysis of body composition but also the monitoring of contingent changes in body composition within the framework of the long term observation of an individual or of population groups.

FILE CHARACTERISTICS AND APPLIED METHODS

The mixed file was comprised of 30 probands in total, 17 of whom were boys (10–14 years) and 13 were girls (11–13), without any special motion load (43% female gender, 57% male gender). All of the probands were monitored in the Biomedicine Laboratory, Faculty of Physical Education and Sport, Charles University in Prague. Testing by DEXA method was carried out in cooperation with the Densitometry Department, Central Military Hospital in Prague. The respective measurements were carried out all at once, i.e. the proband was tested by all specific methodics within one visit. The probands were apprised of the goal and process of all of the testing in advance. With respect to the probands’ age, we sought their parents’ approval. One of the basic requirements was to minimize the influences of the environment as well as the examiner because they affect the test results as errors. The examiner’s influence was minimized in the following manner: it was always the same person who did all of the probands’ values (except for that done by the DEXA method) and whose measurement reliability was verified using the test-retest method.

From the basic anthropometric parameters, we measured stature (cm) and body weight (kg). For measurement of the skinfolds’ thickness we used the Best type caliper (face, chin, biceps, triceps, forearm, back, thorax I, thorax II, abdomen, hip, thigh I, thigh II, calf II) and the Harpenden caliper (skinfolds for so-

matotype – biceps, triceps, spina, scapula, calf I). The circumference measurements (cm) – particularly the circumference of the arm, forearm, thigh, waist and hip – were determined by using an inelastic measuring tape with an accuracy of 0.1 cm. The breadth measurements (mm) – particularly the wrist breadth, breadth of the distal epiphysis of the humerus and ankle breadth – were measured by using a slide gauge with an accuracy of 0.5 mm. The BMI index ($\text{kg}\cdot\text{m}^{-2}$), WHR index and somatotype were determined according to Heath and Carter (1967) by using the SURVEY software in its 2.95 version.

To determine body composition, we used the DEXA reference method (HOLOGIC type, 11.1:7 version, Delphi W model (S/N 70522), measurement of the skinfolds' thickness according to Pařízková (1977, 38) – SKF_1 (prediction equations by Pařízková, 1977, 38), SKF_2 (prediction equations by Bunc et al., 1998, 1), method of body composition according to Matiegka (1921), bioelectric impedance – BIA (Bodystat 500 – BIA_1 – software ANTROPOS 2.3 (1995), BIA_2 – Bunc et al. (1998, 1), BIA_3 – OMRON BF 300, BIA_4 – TANITA TBF – 551).

TABLE 1

Values of the monitored probands' selected parameters ($n = 30$), the values are presented in the form of average $\pm$ standard deviation

		Boys ($n = 17$)	Girls ($n = 13$)
BMI ($\text{kg}\cdot\text{m}^{-2}$)		17.8 ± 2.0	17.9 ± 1.9
WHR		0.82 ± 0.04	0.78 ± 0.03
Somatotype components	Endomorphic	1.1 ± 0.7	1.1 ± 0.4
	Mesomorphic	3.3 ± 1.1	2.7 ± 1.1
	Ectomorphic	3.9 ± 1.1	4.0 ± 1.0
Skinfolds (mm)	Face	3.9 ± 0.8	3.0 ± 0.6
	Chin	3.4 ± 1.1	2.9 ± 0.7
	Thorax I	4.1 ± 1.2	3.3 ± 1.1
	Thorax II	3.9 ± 1.6	3.8 ± 1.3
	Arm (triceps)	3.6 ± 1.5	3.4 ± 0.8
	Arm (biceps)	4.0 ± 1.9	3.2 ± 1.2
	Forearm	3.5 ± 1.2	3.2 ± 1.3
	Hip	4.6 ± 2.2	5.1 ± 1.8
	Abdomen	9.1 ± 4.3	8.8 ± 3.3
	Back	4.6 ± 1.6	4.4 ± 1.1
	Thigh I	5.4 ± 1.4	5.0 ± 1.5
	Thigh II	7.6 ± 1.3	8.2 ± 1.5
	Calf I	5.9 ± 1.4	5.2 ± 1.0
	Calf II	6.2 ± 1.9	6.5 ± 2.1
Σ of 10 skinfolds (mm)		48.7 ± 14.6	45.0 ± 10.0

TABLE 2

Fat mass values (%) determined by different methodics

	Fat (%) SKF_1	Fat (%) SKF_2	Fat (%) by Matiegka	Fat (%) BIA_1	Fat (%) BIA_2	Fat (%) BIA_3	Fat (%) BIA_4	Fat (%) DEXA
Boys ($n = 17$)								
Average	12.1	9.9	12.6	5.5	6.9	16.8	15.0	16.6
SD	3.9	3.7	2.9	2.4	1.5	5.0	3.8	3.3
Min	7.2	4.4	8.7	1.5	4.8	10.1	7.9	12.1
Max	19.2	16.9	17.7	10.1	10.3	24.8	22.4	25.2
Girls ($n = 13$)								
Average	13.7	9.1	11.5	5.5	18.8	18.1	19.4	20.6
SD	2.5	2.8	2.5	2.3	2.7	3.3	2.6	3.4
Min	9.0	3.8	7.7	2.2	14.0	13.3	15.4	15.7
Max	17.7	14.6	16.1	9.7	22.6	22.8	24.8	26.9

Legend:

The values are presented as an average $\pm$ SD (standard deviation).

SKF_1 – measurement of the skinfolds' thickness, prediction equation according to Pařízková (1977)

SKF_2 – measurement of the skinfolds' thickness, prediction equation according to Bunc et al. (1998)

BC Matiegka – body composition by Matiegka's method (1921)

BIA_1 – Bodystat 500, ANTROPOS 2.3 software (1995)

BIA_2 – Bodystat 500, prediction equation, Bunc et al. (1998)

BIA_3 – OMRON BF 300 – prediction equation as part of the device software result

BIA_4 – TANITA TBF 551 – prediction equation as part of the device software result

DEXA – dual energy X-ray absorptiometry

TABLE 3

Correlation analysis and t-test for pairing values of DEXA methodics compared with other chosen methodics

A) Boys

	R²	R	P (t-test)
SKF ₁ /DEXA	0.808	0.899**	< 0.01
SKF ₂ /DEXA	0.696	0.834**	< 0.01
BC Matiegka/DEXA	0.643	0.802**	< 0.01
BIA ₁ /DEXA	0.479	0.692**	< 0.01
BIA ₂ /DEXA	0.536	0.732**	< 0.01
BIA ₃ /DEXA	0.540	0.735**	N. S.
BIA ₄ /DEXA	0.493	0.702**	N. S.

B) Girls

	R²	R	P (t-test)
SKF ₁ /DEXA	0.072	0.268	< 0.01
SKF ₂ /DEXA	0.895	0.946**	< 0.01
BC Matiegka/DEXA	0.548	0.740**	< 0.01
BIA ₁ /DEXA	0.672	0.820**	< 0.01
BIA ₂ /DEXA	0.579	0.761**	N. S.
BIA ₃ /DEXA	0.569	0.754**	N. S.
BIA ₄ /DEXA	0.137	0.370	N. S.

Legend:

* p < 0.05

** p < 0.01

R² – determination coefficient

R – Pearson's correlation coefficient

N. S. – insignificant difference

P (t-test) – significant difference of fat mass averages (%) by using the pairing t-test

We used NCSS 6.0.21 Jr – Demo (Copyright © 1996 by Jerry Hintze) and the Microsoft Excel 1997, 2002 programs for data analysis and its statistical treatment.

We used basic statistical characteristics, including position measurement (using an arithmetic average), variability measurement (using standard deviation) for the (quantitative data) file description. We used the linear regression method and correlation analysis to express relationships between the examined probands' body characteristics. We used correlation analysis and the pairing t-test to establish a mean value for the comparison of the results of fat mass measurements (%) by selected methods. With respect to the above mentioned errors in measurement, the objectively significant difference in the evaluation of the methods' differentness was determined at 1.5–2% of the fat mass value (Bunc, 2001, 48; Bunc et al., 2001, 105). The relevance of such relationships and differences between the single methods was considered at p < 0.01 and p < 0.05 levels.

RESULTS

We are not presenting the basic statistical characteristics of stature and body weight with respect to the examined probands' age spread (10–14 years) and to the low numbers of probands in the subfiles structured according to age. The aim of the study was focused on the examination of correspondence between the methods used for the determination of body composition; therefore, we present the basic statistic characteristics of selected indexes, somatotype components and skinfolds in TABLE 1. These data serve as a basis for assessment of the output values.

Inhomogeneity of the anthropometric parameters and body composition parameters as well can be caused by many factors (biological age, individual's variability, etc.).

The single somatotype components were determined based on the anthropometric parameters. It is necessary to mention that a child's distribution and relationship of morphological components differ from an adult's. All three components can change in connection with the type of growth (Riegerová et al., 1998, 61).

DISCUSSION

Anthropometry serves as a basis for determining the morphological characteristics of body and body composition (FM, FFM). It does not include only the measurement of body circumferences, breadths and lengths but also the measurement of the skinfolds' thickness that further serve for the calculation of the amount of subcutaneous fat. The possibility of the determination of various subparameters, e.g. skinfold thickness in the abdominal area, or other coefficients, allows us, among other factors, to characterize the fat mass distribution. Epidemiologic studies show that not only the total amount of body fat, but also its distribution is important for the distribution of the so called lifestyle diseases. The intra abdominal fat in adults is referred to as clinically the most severe type of fat mass distribution (Maffeis et al., 2001, 179; Teixeira et al., 2001, 433; Chan et al., 2003, 441). There are various anthropometric parameters and indexes, such as, e.g. BMI and waist circumference, that are commonly used for the estimation of fat mass, assessment of its distribution and for the evaluation of the relationship between the obesity and risk factors of cardiovascular diseases. BMI, however, does not reflect the exact proportion of fat and fat free mass. The amount of fat mass (%) increases with age and is higher in women than men, but these differences may not be involved with BMI (WHO, 1995). In comparison to BMI, the fat mass (%) has a greater predicative ability and is more tightly connected with the health hazards

TABLE 4

Objectively significant/insignificant difference in fat mass quantity (%) observed by single methods for determination of body composition in boys and girls (the values are presented in %; **< 1.5–2% = objectively insignificant difference**; **> 1.5–2% = objectively significant difference**)

	SKF ₂	BC Matiegka	BIA ₁	BIA ₂	BIA ₃	BIA ₄	DEXA
SKF ₁ b	-2.2	+0.5	-6.6	-5.2	+4.7	+2.9	+4.5
g	-4.6	-2.2	-8.2	+5.1	+4.4	+5.7	+6.9
SKF ₂ b		+2.7	-4.4	-3.0	+6.9	+5.1	+6.7
g		+2.4	-3.6	+9.7	+9.0	+10.3	+11.5
BC Matiegka b			-7.1	-5.7	+4.2	+2.4	+4.0
g			-6.0	+7.3	+6.6	+7.9	+9.1
BIA ₁ b				+1.4	+11.3	+9.5	+11.1
g				+13.3	+12.6	+13.9	+15.1
BIA ₂ b					+9.9	+8.1	+9.7
g					-0.7	+0.6	+1.8
BIA ₃ b						-1.8	-0.2
g						+1.3	+2.5
BIA ₄ b							+1.6
g							+1.2

Legend:

The value with “+” sign signifies that it is higher in a column than in a row (e.g. value from BC Matiegka is higher by 0.5 against the value from SKF₁).

The value with “-” sign signifies that it is lower in a column than in a row (e.g. value from SKF₂ is lower by 2.2 against the value from SKF₁).

that arise from its amount and distribution in the body (Deurenberg et al., 1989, 624; Deurenberg-Yap et al., 2003, 81).

We find significant relationships in the group of boys, not only between the total amount of fat mass (%) from DEXA and anthropometric indexes BMI ($R^2 = 0.475$, $R = 0.689$, $p < 0.01$), WHR ($R^2 = 0.412$, $R = 0.642$, $p < 0.01$), but also between the amount of fat mass (%) from DEXA_{TRUNK} and anthropometric indexes BMI ($R^2 = 0.297$, $R = 0.545$, $p < 0.05$) and WHR ($R^2 = 0.416$, $R = 0.645$, $p < 0.01$). On the other hand, we found an insignificant relationship in the group of girls between the fat mass (%) from DEXA_{TRUNK} and anthropometric indexes BMI ($R^2 = 0.252$, $R = 0.502$, N.S.) and WHR ($R^2 = 0.131$, $R = 0.362$, N.S.), while the relationship of BMI and the total amount of fat mass (%) from DEXA is significant ($R^2 = 0.669$, $R = 0.818$, $p < 0.01$). We noticed a high interdependence between the waist circumference and the total amount of fat mass (%) as shown by DEXA in boys ($R^2 = 0.523$, $R = 0.723$, $p < 0.05$) and girls ($R^2 = 0.753$, $R = 0.868$, $p < 0.01$), but also between the amount of fat mass (%) from DEXA_{TRUNK} in boys ($R^2 = 0.503$, $R = 0.709$, $p < 0.01$) and girls ($R^2 = 0.333$, $R = 0.577$, $p < 0.01$). Further, there are markedly close relations between the single somatotype components and the total amount of fat mass (%) from DEXA in boys ($R^2 = 0.276$ – 0.743 , $R = 0.525$ – 0.862 , $p < 0.01$, $p < 0.05$) and girls ($R^2 = 0.410$ – 0.706 , $R = -0.640$ – 0.840 , $p < 0.01$). We find a high dependence in boys between the skinfold thickness (mm), mostly in the upper part

of body, and the total amount of fat mass (%) from DEXA ($R^2 = 0.419$ – 0.702 , $R = 0.647$ – 0.838 , $p < 0.01$), or the amount of fat mass (%) from DEXA_{TRUNK} ($R^2 = 0.288$ – 0.724 , $R = 0.537$ – 0.851 , $p < 0.01$). We also noticed a high dependence in girls between the skinfolds' thickness (mm), mostly in the upper part of the body, and the total amount of fat mass (%) from DEXA ($R^2 = 0.359$ – 0.872 , $R = 0.599$ – 0.934 , $p < 0.01$), but the relationship between the amount of fat mass (%) from DEXA_{TRUNK} and some of the skinfolds (mm) was less close ($R^2 = 0.328$ – 0.618 , $R = 0.573$ – 0.786 , $p < 0.05$, $p < 0.01$). There is a markedly highly significant relationship between Σ of skinfolds and the total amount of fat mass (%) as shown by DEXA in boys ($R^2 = 0.767$, $R = 0.876$, $p < 0.01$) and girls ($R^2 = 0.893$, $R = 0.945$, $p < 0.01$), or the amount of fat mass (%) as shown by the DEXA_{TRUNK} measurement in boys ($R^2 = 0.610$, $R = 0.781$, $p < 0.01$) and girls ($R^2 = 0.417$, $R = 0.646$, $p < 0.01$). This different dependence between the skinfolds and the amount of fat mass (%) as shown by DEXA or determined by DEXA_{TRUNK} methods, confirms intersexual differences in fat mass distribution (Baumgartner et al., 1990, 223).

We can suppose, for the DEXA method, based on the hints given in the literature, that it sufficiently represents an accurate technique for the determination of body composition and is able to recognize even small changes in the amounts of fat mass or fat free mass. The validity of the DEXA method was not the subject of this study, yet we supposed, based on the hints given in the

literature (Maud et al., 1995, 217; Pařízková, 1998a, 3; Brodie et al., 1999, 807; Bunc, 2001, 48) that we could use it as a reference method. In evaluation of body composition by the DEXA method, we noticed higher average values of fat mass in girls ($20.6 \pm 3.4\%$) than in boys ($16.6 \pm 3.3\%$). Heyward et al. (1996, 90), Bláha et al. (2001, 97) mention the marked intersexual differences in the development of the values of the proportion of human body fat components, which already appear before adolescence. These differences mainly result from the different somatotype development of both genders and from different starting times of adolescence spurt. Sexual differentiation in fat distribution appears already in the middle infancy stage; it grows strong in adolescence and persists in adult age.

The positive advantage of the DEXA method is that it reduces measurement error caused by the person or persons providing the measurement (biological error). The indicated measurement error is smaller than 3% for fat tissue, 1.1 kg for muscle tissue and 30g for bones (Maud et al., 1995, 216). On the contrary, the great disadvantage of most of the reference methods is that their availability is limited in our conditions due to their high technical and financial demands and therefore they are virtually impracticable for field population studies. For that reason there is a current trend to simplify the process of the field evaluation of body composition, and the DEXA method is mainly used today for verification of derived methods (so called III level methods) that are readily available, not time consuming, technically and financially acceptable but less exact (e.g. anthropometry, BIA) (Dlouhá et al., 1998, 8; Pařízková, 1998a, 1; Bunc et al., 2001, 103; Malá et al., 2008).

Each of the physical measuring methods has its error sources that have to be taken into account. It is partly the so called biological error, i.e. an error caused by the device operator. The errors of the methods itself can be divided into errors connected with software and so, with the use of prediction equations, in which errors can reach up to tens of a percentage (up to 80% of the measured value) and errors connected with the hardware (error of the measuring device itself, places of measurements, electrode configuration, measuring frequency, hydration, etc.). The total error is then the sum of the single fractional errors of both software and hardware (Roche et al., 1996, 15; Bunc, 2001, 50). The total error of the anthropometry and BIA method varies between ± 3 –6% of the total fat mass and the error related to the prediction equations varies between ± 3 –4% (Maud et al., 1995, 221). The observed differences in fat mass values (%) point to a considerable disparateness of the methodics, but they are mainly caused by the differentness of the single prediction equations used for the final calculation of the fat mass amount (%). We noticed a 15.1% difference in the group of girls between the low-

est and highest measured value of fat mass (%), which is even bigger by 3.8% as measured against the boys' values (girls – minimal value – BIA₁ Bodystat 500 with use of prediction equation of ANTROPOS 2.3 software (1995) – $5.5 \pm 2.3\%$; maximal value – DEXA – $20.6 \pm 3.4\%$). We noticed a 11.3% difference in the group of boys between the lowest and highest measured value of fat mass (%). There was a minimal value of – BIA₁ Bodystat 500 with the use of a prediction equation calculated by ANTROPOS 2.3 software (1995) – $5.5 \pm 2.4\%$; there was a maximal value of – BIA₃ (OMRON BF 300 – with the prediction equation being part of the calculation by the device's software) – $16.8 \pm 5.0\%$. The average values of fat mass (%) determined by means of anthropometry and bioimpedance were lower by 1.2–15.1% in the group of girls in comparison to the amounts of fat mass as shown by the DEXA method. The average values of fat mass as shown by anthropometry and BIA were lower by 1.6–11.1% in boys in comparison to the amounts of fat mass as shown by the DEXA method. The values of fat mass (%) as shown by BIA measured by the OMRON BF 300 device (prediction equation as part of the calculation by the device's software) were higher by even 0.2% on average as opposed to the DEXA method. Most of the prediction equations used (BIA₂₋₄) provide lower values of fat mass (%) in comparison to the DEXA method, the most significant differences being in prediction equations for SKF_{1,2}, BIA₁. Gutin et al. (1996, 290) compared the DEXA method, the measurement of 7 skinfolds and the BIA method in children ($n = 43$; boys – 10.33 ± 0.58 years, girls – 10.27 ± 0.63 years). They found higher values of fat mass (%) in the group of girls based on the single methods: the value was higher by 3.7% in girls as opposed to the boys by the DEXA method; by 3.4% by the measurement of skinfold thickness and even by 4.4% using the BIA method. They also noticed that the highest average values of fat mass (%) were measured by the DEXA method while the lowest average values of fat mass (%) were determined by measurement of the skinfold thickness. The correlation analysis shows a good match of the DEXA method and other chosen methodics for the determination of body composition in boys as well as in girls (boys – $R^2 = 0.479$ – 0.808 , $R = 0.692$ – 0.899 , $P < 0.01$; girls – $R^2 = 0.548$ – 0.895 , $R = 0.740$ – 0.946 , $P < 0.01$). To assess the methods' mutual differences, it is necessary to observe the mutual correlation of the single methods. The differences' analysis, using the t-test for pairing values, showed that there mostly is statistically significant difference between the chosen prediction equations for the determination of body composition in both groups of boys and girls. Heymsfield et al. (1990, 216), Bunc (2001, 48; Bunc et al., 2001, 105) consider 1.5–2% to be the objectively significant difference between the amount of fat mass (%) measured by the comparative

methods. That means if the difference in values of fat mass (%) measured by various methods is lower than 1.5–2% the methods can be considered to be compatible. In our case, we found mostly the objectively significant differences between the single methods for the determination of body composition (TABLE 4).

As we have already mentioned, the prediction equations represent, besides the financial and technical demands, the major difficulty of the usability of the current methods for the determination of the body's composition. Determination of prediction equations that will respect, besides the ages, gender, and level of physical activity, also the individual's body composition or its level of fat amount represent the basis for a successful use of the specified methods (Deurenberg et al., 1989, 625). There is no universal prediction equation that could be used for all of the population groups and that would respect the whole range of fat mass values at the same time (Slaughter et al., 1988, 722; Deurenberg et al., 1989, 625). It is necessary to remember that many of the prediction equations were formed more than 25 years ago (e.g. equation according to Pařízková, 1977). Today's population differs from the population the prediction equations were tested on. Many of the equations were designed for a normal population and its use for sportspeople is therefore not suitable. Some of the equations are often taken over from foreign studies, but somatotype and racial characteristics are again different.

We know, based on the hints given in the literature, that the minimal level of fat mass (%) that is considered to be physiological is 4–6% for men and 8–12% for women (Heyward et al., 1996, 92), and we can suppose that these values will be similar for children if not slightly higher. Based on this thesis it is evident that the minimal or average values of fat mass (%) calculated by some of the methodics seem to be unrealistic (TABLE 2).

Using caliperation, we calculate the percentage of fat mass (%) based on the sum of the corresponding skinfolds. We observed approximately the same dependence of Σ of skinfolds/DEXA ($R^2 = 0.767$, $R = 0.876$, $p < 0.01$) and SKF_1 /DEXA ($R^2 = 0.808$, $R = 0.899$, $P < 0.01$), or SKF_2 /DEXA ($R^2 = 0.696$, $R = 0.834$, $P < 0.01$) in the group of boys. While in girls, we noticed a highly significant relationship of Σ of skinfolds/DEXA ($R^2 = 0.893$, $R = 0.945$, $p < 0.01$) and SKF_2 /DEXA ($R^2 = 0.895$, $R = 0.946$, $P < 0.01$), but insignificant SKF_1 /DEXA ($R^2 = 0.072$, $R = 0.268$, $P < 0.01$). The above said results, in fact the mathematical approximations (using the equations for calculation of fat mass percentage), bring other errors into the final determination of the fat mass amount (%). Using the equations for the calculation of fat mass (%) from skinfolds' thickness or other anthropometric parameters, is, therefore, questionable. Although the public is used to this quantity, monitoring of the sum of the corresponding skinfolds

or skinfolds itself (not excepting other anthropometric parameters) would be in many cases sufficient for the determination of body composition.

Riegerová (1995, 16, 17) draws attention to a difference between the final percentage of fat fraction determined by caliperation according to Pařízková and the value according to Matiegka. She sees this difference as a consequence mainly of the different localization of skinfolds in lower extremities that affects the calculation. The differences in evaluation increase with growing thickness of fat mass, yet the age, physique type and harmony of distribution of fat tissue represent, among others, important factors as well. The comparison of evaluations of fat mass by anthropometric methods and by Bodystat 500 (Riegerová & Přidalová, 1996, 32, 33) further shows that the bioimpedance measurement by Bodystat 500 fits in the results obtained by caliperation. They also mention in the results the possibility of using regression equations for the calculation of skeleton weight (kg) as a specification of another physique component when using bioimpedance. A decisive source of inaccuracy in the BIA method are mainly the prediction equations, much as in measurement by the skinfold thickness method. Bunc et al. (1999, 102) shows insignificant differences in resistance values when using Bodystat 500 and Bodystat 2000-M (in 50 kHz frequency). Nevertheless, he adverts to a problem with the use of prediction equations for the conversion of fat mass percentage from BIA. He mentions that the critical limit for the determination of fat mass is the age of 10 years. Therefore, it is necessary to use specific prediction equations that respect the proband's age. A fairly big problem is still represented by measurement conditions, also including the skill and experience of the measuring personnel.

However, the determination of body composition by means of the BIA method is also not trouble free. The BIA method measures the total body water (TBW) and counts on 72.3% of average body hydration and FFM and is determined based on the relationship of $FFM = TBW \cdot 0.732^{-1}$ (Luskaski et al., 1985, 811). It is necessary to emphasize that the amount of water in an organism depends on the individual's age, weight and gender and that it individually varies according to intake and output. The real measured hydration of FFM varies between 61–82% (Roche et al. 1996, 263). In children, the proportion of total body water in their weight is higher; it is approximately 77% in newborns. Sexual differentiation does not develop until the postadolescent period, when the hydration rate increases in boys and decreases in girls. From the development point of view, it is not only the development of total body water (TBW) but also the development of its fractions – ECT and ICT – that are substantial. The proportion of ECT is relatively stable at the age of 12–18 years, whereas the proportion

of ICT increases in boys in this period and decreases in girls. The newest studies confirm that increasing age is accompanied by a decrease in body hydration, only in terms of a decrease in the TBW amount, and it was noticed that the decrease in TBW is different for men and women (Heyward et al., 1996, 99). We observed mostly a good match between BIA/DEXA in boys ($R^2 = 0.479-0.540$, $R = 0.692-0.735$, $P < 0.01$, N. S.) and in girls ($R^2 = 0.569-0.672$, $R = 0.754-0.820$, $P < 0.01$, N. S.), but also among each other BIA (TABLE 4). To determine FFM and fat mass (%) it is, however, necessary to set out the corresponding prediction equations for each member of the group of persons, since these are a limiting element for the practical use of these methods (Bunc et al., 2001, 105).

CONCLUSION

The results confirm the possibility that anthropometric parameters can be used not only for the evaluation of body composition in terms of the amount of fat mass (%) in particular, but also for the assessment of its distribution. A significant match of a number of anthropometric parameters and the total amount of fat mass (%) as measured by DEXA or DEXA_{TRUNK} was observed in both groups of boys and girls. A good match of the DEXA method and other chosen methodics for the determination of body composition was found in both boys and girls, but from the statistical and objective significance points of view, we deduce a considerable differentness of single methodics mainly due to the differentness of prediction equations. Most of the used prediction equations (BIA₂₋₄) provide lower values of fat mass (%) in comparison to the DEXA method, the most significant differences being in prediction equations for SKF_{1,2}, BIA₁.

Monitoring of various anthropometric parameters is, due to its noninvasiveness and relatively low demands on financial and technical needs, advisable for extensive epidemiological studies. The monitoring and use of anthropometric parameters and derived indexes in clinical practice help us to observe their relationships to the function of the organism, with other indexes characterizing health hazards. It would contribute, among others, to an evaluation of the healthy as well as the ill organism and to a definition of needed arrangements supporting human health.

Each of the physical measuring methods has its error sources that have to be taken into account. It is partially so called biological error, i.e. an error caused by the device operator. The errors of the methods itself can be divided into errors connected with hardware (error of the measuring device itself, places of measurements, electrode configuration, measuring frequency, etc.) and

then errors connected with software and so with the use of prediction equations, in which errors can reach up to tens of a percentage (up to 80% from the measured value). The specific prediction equations that respect, not only the ages, gender, and level of physical activity of the persons examined, but also the individual's body composition or its level of fat amount represent the basis for a successful use of these methods for the determination of body composition. Unfortunately, there is no universal prediction equation that could be used for all of the population groups.

The observed relationships, presented results and output cannot be generalized for the entire population, they can be used only for this file.

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MOŽNOSTI VYUŽITÍ VYBRANÝCH METOD PRO STANOVENÍ TĚLESNÉHO SLOŽENÍ U DĚTÍ V OBDOBÍ PUBERTY (Souhrn anglického textu)

Lidské tělo můžeme v podstatě rozdělit do několika komponent, které mezi sebou vytváří vzájemné vztahy. Mezi nejvýznamnější komponenty tělesného složení řadíme tělesný tuk (FM), tukuprostou hmotu (FFM) a celkovou tělesnou vodu (TBW). Tělesné složení, v nejčastějším pojetí jako velikost podílu depotního tuku a aktivní hmoty, vytváří výrazný somatický znak, který se charakteristicky rozvíjí v závislosti na věku, pohlaví a stupni tělesného rozvoje. Obecně lze parametry tělesného složení stanovovat množstvím metod, které se liší jak přístrojovou a personální náročností, tak i přesností stanovení sledovaných dat. Hlavním cílem této práce bylo posoudit možnosti využití metod pro stanovení tělesného složení, které jsou v současné době k dispozici v laboratorních a terénních podmínkách, u dětí.

Do studie bylo zahrnuto celkem 30 probandů, z toho 17 chlapců a 13 děvčat ve věku 10–14 let. Hodnotili jsme základní antropometrické parametry (tělesná výška, tělesná hmotnost, BMI, WHR, obvodové a šířkové rozměry, komponenty somatotypu podle Heathové a Cartera). Pro stanovení tělesného složení jsme použili referenční metodu DEXA (typ HOLOGIC), měření tloušťky kožních řas podle Pařízkové (Bestův kaliper), metodu podle Matiegky (1921), bioelektrickou impedanci – BIA (Bo-

dystat 500, OMRON BF 300, TANITA TBF – 551). Pro přepočet na množství tělesného tuku (%) jsme zvolili různé predikční rovnice.

U chlapců i děvčat jsme našli významnou závislost mezi některými antropometrickými parametry (obvod pasu, obvod boků, komponenty somatotypu, tloušťka kožních řas) a množstvím tělesného tuku (%) z metody DEXA, resp. $DEXA_{TRUP}$. U chlapců i děvčat byla nalezena dobrá shoda metody DEXA a ostatních zvolených metodik pro stanovení tělesného složení. Významné rozdíly mezi jednotlivými metodami ukazují především na odlišnost zvolených predikčních rovnic.

Klíčová slova: tělesné složení, komponenty tělesného složení, metody pro hodnocení tělesného složení.

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