Some Differences in Body Composition in Moscow Adolescent Children According to the Level of their Physical Activity: Comparison of Anthropometric and Bioelectrical Impedance Methods of Assessment

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INTRODUCTION

The study of body composition gives additional, physiological dimension to classical research of age changes during growth and development, promote further understanding of the intra- and intergroup variability, play an important role in applied research for assessing nutritional differences, or those connected with disease, physical activity and other factors influencing growth.

First equations for predicting the size of body mass compartments on the basis of anthropometric measurements were introduced at the beginning of the 20th century (Matiegka, 1921). Later they were developed and elaborated by many researchers. In the second half of the 20th century other experimental methods appeared: densitometric, isotope dilution, absorptiometric, bioelectrical and others (for review of the methods see Zemel and Barden, 2004).

Among several bioelectrical methods, the one that is widely used is bioelectrical impedance analysis (BIA). It is based on the differences in human body tissue resistance (impedance) to a small electrical current. Thus, adipose tissue has much higher resistance as compared to those tissues that contain a lot of water (extracellular fluid, blood, muscle, etc.) and comprise the main part of the fat-free mass (Baumgartner, 1996).

The BIA technique is popular in anthropological studies as non-invasive and applicable for field research. It can be applied technically to all subjects irrespective of their ethnicity, age, sex and health status. However in practice the BIA studies of body composition in children are less numerous due to some methodological problems connected with the changing quantity of water in a growing organism, technical problems of placing electrodes on small hands and feet, etc. (Baumgartner, 1996).

The present study was aimed at the assessment of body composition in 12-17-year-olds using anthropometric and BIA methods. The impedance estimates were correlated with anthropometric measurements characterizing three body compartments: fat, muscles and bone. Another goal was to analyze body composition differences in groups of children according to the level of their physical activity.

MATERIALS AND METHODS

The data for the present study were collected in 2005 in different Moscow schools. 195 girls and 259 boys from 12 to 17 years old were investigated cross-sectionally and divided into three groups according to their physical activity status: 1 – those who did not take part in regular physical exercise (44 boys and 50 girls); 2 - those who took part in special sports programs in general education schools (82 boys and 82 girls); 3 – students of special sports schools with high sports ranking (133 boys and 63 girls). All children were of the same ethnicity (Russians).

Anthropometric program included about 30 measurements taken according to the standard techniques (Bounak, 1941; Weiner and Lourie, 1981). Subjects were measured bare-feet, wearing only underwear. Weight was taken using a battery-operated digital weighing scale (precision 100g).

Height, arm and leg length (sum of the heights of iliospinale and symphysion points divided by two) were measured using an anthropometer (1mm precision). Body diameters (biiliac, bicristal, chest width and chest depth) were measured using a spreading caliper (1 mm precision). Chest, waist, hips, arm, forearm, thigh and calf circumferences were measured using a plastic measuring tape (5 mm precision). Chest circumference was measured at the union of the 3rd and 4th sternebrae. Subcutaneous skinfolds (subscapular, biceps, triceps, forearm, abdomen, suprailiac, thigh and calf) were measured using a skinfold Harpenden caliper (1 mm precision). Elbow, wrist, knee and ankle widths were measured with a special sliding caliper (1 mm precision).

The body mass index (BMI) of the studied subjects was calculated as weight (kg) divided by height^2(m).

Total fat (fat mass) was calculated by Matiegka's equations (1921):

$FM = d \cdot S \cdot k$,

where FM – fat mass (kg), d - average thickness of subcutaneous skinfolds (mm), S - body surface (cm^2), k = 0.13.

Subcutaneous fat mass (SFM) was calculated according to Skerlj (Skerlj, 1959; Brodar, 1960; cit. Smirnova and Shagurina, 1981):

$SFM = S \times (M/2 - k) \times 0.9$,

Where SFM – subcutaneous fat mass (kg), S – body surface (cm^2), M – average thickness of subcutaneous skinfolds (mm), k – skin thickness (0.7 mm – for children).

Fat-free mass (FFM) was calculated as Body mass minus Fat mass (FM).

Besides anthropometric measurements, stages of secondary sexual characteristics were evaluated, age at menarche was assessed by status quo method. Somatotypes were determined according to Shtefko and Ostrovsky's method (1929).

Diastolic and systolic blood pressure (BP), pulse rate, body temperature and dynamometry, or hand grip (both hands) were measured in all children. In the text they are called "functional traits".

For the bioelectric impedance analysis a single-frequency system "ABC-01 Medass" (Nikolaev, 2001) was used. It operates with a frequency of 50kHz and is analogous to other such systems. It uses four electrodes attached to the hand and ipsilateral foot in the standard fashion (Baumgartner, 1996).

The BIA technique gives two indices of tissue impedance – active resistance (R_Z) and reactive resistance, or reactance (Z_C). The analyzer also measures phase angle ϕ**.** The analyzer is equipped with the original software, which gives the estimates of body compartments (Nikolaev, 2001).

Active resistance (R_Z) is positively connected with fat mass (FM) and negatively – with total body water (TBW) and fat-free mass (FFM): the bigger is R_Z value, the more is fat mass; reactance (Z_C) is positively connected with active cell mass in FFM (Nikolaev et al., 2004). It may be assumed that these two measurements are the most objective, while further estimates of body compartments are derivatives of these measurements.

Statistical analysis included the calculations of basic statistical parameters for the studied group of children. The procedure of standardizing with standard scores (Z-scores) being calculated for each child and each measurement was also used. Later it allowed summarizing the results according to different categories of the level of physical activity irrespective of the age of the children. To reveal the relationships between characteristics of tissue resistance and morphological traits some methods of multivariate statistical analysis were used. To evaluate the intergroup differences according to physical activity level one-way ANOVA was applied. All calculations were performed with STATISTICA 6.0. Software package.

RESULTS AND DISCUSSION

Means and standard deviations of some anthropometric measurements, BIA measurements and the calculated estimates of body components are given in Table 1. Due to a large number of investigated traits it is hardly possible to present the corresponding figures for all of the traits. In spite of a relatively small sample size the given values can be characterized as reliable. It should be noticed that the estimates of body fat calculated by anthropometric methods are systematically lower than those calculated by BIA methods. Age changes and corresponding sex differences are discussed below in this section.

Bioimpedance Characteristics and Morphological Traits

For greater reliability of the results, further analysis was conducted with standardized estimates (Z-scores).

Before starting the analysis of relationships between bioimpedance characteristics and morphological traits, the normality test was applied for R_Z, Z_C and phase angle ϕ. The results can be seen in Table 2. As the sample size was rather limited, Z-scores were used for analysis. The unimodal distribution for characteristics of bioelectrical impedance was shown. It is also evident that in girls the distribution of the analysed characteristics is closer to normal. It may be suggested that such differences can be explained by differential growth of different body

Table 1: Means and standard deviations of some measurements in Moscow children

	Boys		Girls	
	X	*SD*	*X*	*SD*
12 years	*n=16*		*n=18*	
Stature, cm	150.6	7.13	152.8	10.98
Body mass, kg	43.1	8.04	41.3	10.09
Body mass index (BMI)	18.9	3.25	17.4	2.31
Active resistance (R_Z), ohms	597.1	66.56	640.0	79.33
Reactive resistance, or reactance (Z_C), ohms	61.8	8.62	63.9	8.89
Fat mass (FM-BIA), kg	8.0	4.75	8.1	2.92
Fat-free mass (FFM-BIA), kg	36.6	5.73	36.6	7.11
Total body fat (FM-anthro), kg	6.6	4.77	6.3	3.05
13 years	*n=33*		*n=24*	
Stature, cm	159.3	8.01	155.7	6.99
Body mass, kg	51.1	13.02	45.9	6.92
Body mass index (BMI)	20.0	3.73	18.9	2.23
Active resistance (R_Z), ohms	573.3	89.40	655.4	74.38
Reactive resistance, or reactance (Z_C), ohms	61.6	10.46	68.1	6.66
Fat mass (FM-BIA), kg	9.2	7.14	10.3	3.32
Fat-free mass (FFM-BIA), kg	42.2	9.64	35.9	4.26
Total body fat (FM-anthro), kg	8.8	6.84	7.5	3.12
14 years	*n=60*		*n=20*	
Stature, cm	165.9	9.34	160.9	5.61
Body mass, kg	57.4	13.72	51.5	9.70
Body mass index (BMI)	20.6	3.61	19.8	3.13
Active resistance (R_Z), ohms	552.7	75.55	645.7	67.99
Reactive resistance, or reactance (Z_C), ohms	60.4	7.15	67.3	7.43
Fat mass (FM-BIA), kg	10.7	7.07	13.0	5.78
Fat-free mass (FFM-BIA), kg	47.0	9.15	39.3	5.59
Total body fat (FM-anthro), kg	9.7	7.35	9.8	5.24
15 years	*n=37*		*n=22*	
Stature, cm	173.7	9.69	164.0	4.59
Body mass, kg	64.0	15.39	55.3	7.90
Body mass index (BMI)	21.0	3.73	20.5	2.39
Active resistance (R_Z), ohms	520.3	54.82	648.6	68.51
Reactive resistance, or reactance (Z_C), ohms	58.5	6.18	67.3	8.88
Fat mass (FM-BIA), kg	10.9	7.06	14.9	4.17
Fat-free mass (FFM-BIA), kg	53.3	9.96	41.2	5.12
Total body fat (FM-anthro), kg	8.5	4.19	11.5	5.13
16 years	*n=52*		*n=47*	
Stature, cm	175.5	8.89	163.2	5.63
Body mass, kg	65.8	13.90	56.6	9.08
Body mass index (BMI)	21.2	3.19	21.2	3.09
Active resistance (R_Z), ohms	505.8	58.85	627.3	67.28
Reactive resistance, or reactance (Z_C), ohms	59.5	6.61	68.7	6.95
Fat mass (FM-BIA), kg	10.6	5.82	14.9	5.29
Fat-free mass (FFM-BIA), kg	55.7	9.17	41.8	5.27
Total body fat (FM-anthro), kg	13.2	10.37	12.0	5.86
17 years	*n=21*		*n=22*	
Stature, cm	178.5	7.23	164.0	6.56
Body mass, kg	65.8	8.42	56.0	7.94
Body mass index (BMI)	20.6	2.33	20.8	2.34
Active resistance (R_Z), ohms	524.3	53.70	628.0	60.41
Reactive resistance, or reactance (Z_C), ohms	60.6	8.52	71.5	8.40
Fat mass (FM-BIA), kg	10.0	3.83	14.3	4.68
Fat-free mass (FFM-BIA), kg	54.1	6.22	42.1	4.02
Total body fat (FM-anthro), kg	7.5	2.29	11.6	4.52

components in boys and girls during puberty. In boys this is muscle and skeletal growth in the first place, in girls – adipose tissue.

To study the relationships between the three BIA characteristics the principle component analysis was used. The results are given in Table 3.

As can be seen from Table 3, Factor 1 can be interpreted as a general factor of body resistance with positive loadings for all three characteristics. Factor 2 is bipolar where active resistance R_Z is opposed to two other characteristics (Figs. 1 and 2). The two principal components describe about 98% of the total variance.

Further analysis was performed for two impedance characteristics only - active resistance R_Z and reactance Z_C. Phase angle ϕ was excluded because this parameter mostly gives information about pathological condition of retention of water and reflects the balance of intracellular and extracellular water (Nikolaev et al., 2004).

The relationships of bioimpedance characteristics with the set of anthropometric and functional characteristics were considered. For that multiple regression analysis was used where R_Z Z and Z_C were dependent variables and morphofunctional traits the independent ones.

In Table 4 the estimates of R and p are given for all regression equations for boys and girls. It can be seen that the correlation between all independent variables included in the equation is higher for R_Z than for Z_C.

Evidently, the correlation estimates are higher in boys, with the exception of skinfolds which have higher correlations in girls. This supports the assumption about the role of fat component in the development of somatic traits in girls. At the same time skinfolds have the lowest values of correlation estimates. It somehow contradicts to the description of the method, which postulates the highest correlation between R_Z and fat component (Nikolaev, 2001).

The highest estimates of the multiple correlation coefficients were obtained for the whole set of independent variables, which is not surprising taking into consideration the large number of variables in the analysis – 29 traits.

Besides the above described method, stepwise regression analysis was also used to determine the most informative independent variables. The results of this analysis are given in Table 5. Several conclusions can be made. In average the level of correlation between the corresponding BIA characteristics is somewhat higher in boys. Though the difference is not great, it is confirmed by the number of selected traits: 16 in boys and 14 in girls for R_Z, and 11 and 10 correspondingly for Z_C. It is also interesting to compare the set of selected variables for both sexes.

Only two anthropometric variables appeared in the number of independent variables in all four equations: thigh circumference and wrist width. If the former can be expected as a predictor because it reflects in the best way the degree of

Table 2: Estimates of asymmetry (As) and kurtosis (Ex) in bioimpedance characteristics

	Boys (n=217)		*Girls (n=152)*	
	As	*Ex*	*As*	*Ex*
Active resistance R_Z	0.498***	0.209	0.345*	-0.287
Reactance Z_C	0.656***	1.158***	0.008	-0.266
Phase angle ϕ	0.457***	0.300	0.326*	1.001***

* - p < 0.05
** - p < 0.01
*** - p < 0.001

Table 3: Results of factor analysis (principle component analysis) of bioimpedance characteristics in boys and girls

	Factor loadings			
	Boys		*Girls*	
	Factor 1	*Factor 2*	*Factor 1*	*Factor 2*
Active resistance R_Z	0.904	0.409	0.897	0.413
Reactance Z_C	0.910	-0.395	0.958	-0.234
Phase angle ϕ	0.010	-0.995	0.148	-0.983
Eigenvalues	1.644	1.3112	1.744	1.192
% total variance	54.80	43.72	58.14	39.74

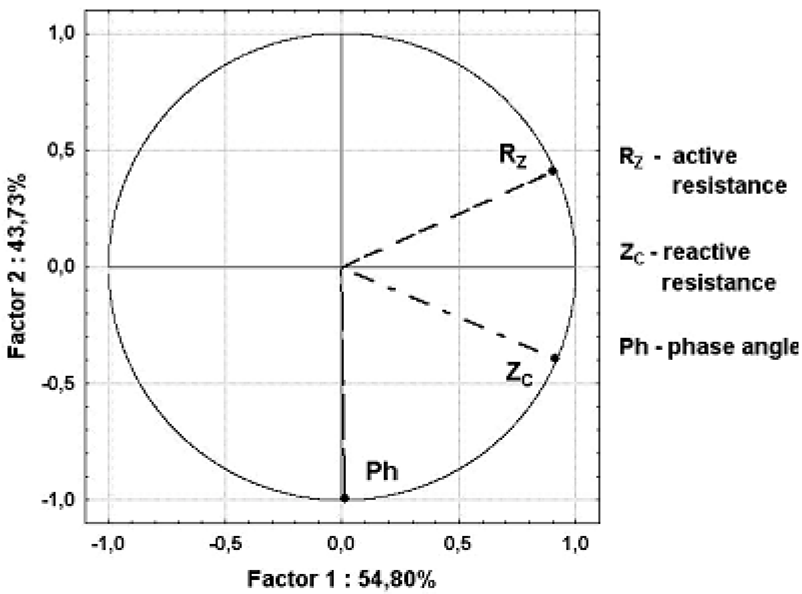

Fig. 1. Principal components analysis of BIA measurements in boys

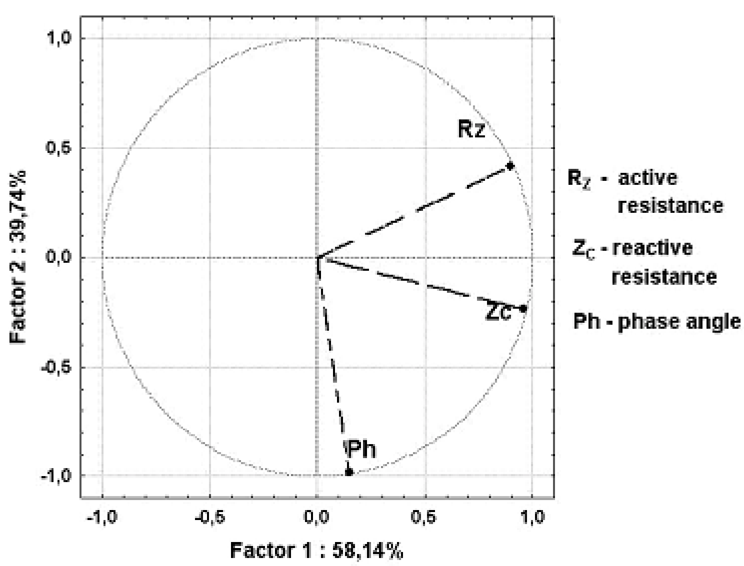

Fig. 2. Principal components analysis of BIA measurements in girls

muscles and fat development in the period of intensive pubertal growth, the wrist width – trait with little variation – became a universal predictor somewhat unexpectedly. It is probably connected with bone development or with the wrist size when placing the electrodes.

There are also two other traits, which entered three out of four equations. They are: forearm circumference and BMI. Thus, BMI which reflects the body shape more than the body size is a good predictor of BIA characteristics.

There are several anthropometric measurements, which are represented for children of only one sex. They are triceps and thigh skinfolds for

Table 4: Results of multiple regression analysis of the BIA characteristics and anthropometric traits, sexual maturation indices and functional characteristics in Moscow adolescents

	Boys				*Girls*			
	R_Z		Z_C		R_Z		Z_C	
	R	*p*	*R*	*p*	*R*	*p*	*R*	*p*
Body circumferences	0.764	<0.000	0.547	<0.000	0.676	<0.000	0.393	<0.003
Skinfolds	0.393	<0.000	0.274	<0.021	0.475	<0.000	0.400	<0.001
Skeletal traits*	0.772	<0.000	0.554	<0.004	0.702	<0.000	0.476	<0.000
Stature and weight	0.598	<0.000	0.454	<0.000	0.543	<0.000	0.372	<0.000
BMI	0.593	<0.000	0.390	<0.000	0.567	<0.000	0.382	<0.000
Functional characteristics	0.504	<0.000	0.277	0.357	0.331	0.293	0.348	0.239
All traits	0.906	<0.000	0.806	0.045	0.880	0.018	0.860	0.068

* Skeletal traits: 4 body diameters, 4 bone width, arm, leg and corpus length.

Table 5: Results of forward stepwise multiple regression analysis of BIA measurements by morphofunctional characteristics in boys and girls

Selected traits	*Boys*		*Girls*	
	R_Z	Z_C	R_Z	Z_C
Forearm circumference	+	+	+	-
Foreleg circumference	+	-	-	+
Arm circumference (strained)	+	-	+	-
Thigh circumference	+	+	+	+
Hip circumference	+	-	-	-
Waist circumference	-	+	+	-
Chest circumference	-	+	-	-
Forearm skinfold	+	-	+	-
Triceps skinfold	-	-	+	+
Biceps skinfold	+	-	-	-
Abdomen skinfold	-	-	+	-
Thigh skinfold	-	-	+	+
Foreleg skinfold	-	-	-	+
Biiliac diameter	+	+	-	
Wrist width	+	+	+	+
Knee width	-	+	-	-
Ankle width	-	-	+	-
Arm length	+	-	-	-
Body mass	+	-	-	-
BMI	+	-	+	+
P (pubic hair)	+	+	-	-
Ax (axillary hair)	+	-	-	-
Facial hair (only in boys)	-	+		
Chest hair (only in boys)	+	+		
Adam's apple (only in boys)	-	+		
Dynamometry (right hand)	+	-	-	-
Pulse rate	-	-	+	+
BP (systolic)	-	-	+	+
BP (diastolic)	-	-	+	+
Number of selected independent variables	16	11	14	10
R	0.889	0.754	0.850	0.744
p	0.000	0.000	0.000	0.000

girls. It supports the significance of fat component in body composition in girls. Among skeletal traits, only biiliac diameter have been included in the regression model for boys.

Interesting differentiation between boys and girls took place for the correlation of sexual maturation indices and functional traits.

Thus, in girls in both regression equations the indices of sexual maturation are absent, including such an important index as age at menarche. At the same time in boys these indices are among the most informative. This difference can be explained first by the age range of the studied sample – from 12 to 17 years old. Girls mature much earlier and the given age range might have been truncated to adequately reflect the process of maturation. An average menarcheal age for the Moscow girls nowadays is 13.0 years (Godina et al., 2003). For the studied sample the corresponding figure was even earlier - 12 years 9.5 months.

Sex difference in the level of correlation may be also interpreted by the fact that hormonal changes in puberty are much more reflected in the body mass components in boys, particularly in the intensive growth of muscles and skeletal traits. In girls, as was already said, the most important role in somatic development belongs to fat component. These morphogenetic differences could probably explain higher correlations between maturation indices and bioelectric body properties.

Similar picture is seen for the functional traits, with the exception that their contribution to the BIA characteristics is practically zero for boys and significant for girls. It can be assumed that cardio-vascular status, which in our case is characterized by pulse rate and two estimates of BP, is more connected with the fat component, hence is more correlated in girls. This can be confirmed by the estimates of canonical correlations (CC) between skinfolds and functional traits: 0.449 for boys (p=.233) and 0.739 for girls (p<0.000).

It is surprising that among traits that were not included into the category of the most informative predictors, happened to be such an important trait as stature. This result contradicts to some literary data, which show that impedance is dependent on overall size (Zemel and Barden, 2004). In our case an important predictor turned out to be BMI. Stature of course is included in the calculation of BMI. But this characteristics is more important for describing body shape than the overall size, and one can think that it is also more important for predicting body composition and conductivity level. One more explanation can be given from the field of applied anthropology. When developing the size typology for clothes, the proportion of large width sizes is more typical for people of average or less-than-average stature (Dunaevskaya and Kurshakova, 1983). At the same time important differences between people according to body components are based on the proportion “fat-water” – two antipodes in terms of electrical tissue conductivity. That is why stature may not be directly connected with the estimates of body components.

Linear regression models describe the interconnections between one dependent variable (in our case – the BIA characteristics) and numerous independent variables. To test the results of the previous analysis canonical analysis was carried out. In case of canonical analysis all impedance characteristics are taken as a whole and correlated with groups of traits.

Canonical analysis gave more detailed picture as compared to regression models. This is not surprising because in canonical analysis all of the bioelectrical characteristics stood as a single complex. From Table 6 one can see that the correlation level is higher in boys. This is true for most of the traits, or groups of traits but the biggest differences are seen for sexual maturation indices (0.859 versus 0.476), which supports the results of multiple regression analysis. At the same time, for functional characteristics the results are different than those derived from the multiple regression analysis. Again the CC are much bigger in boys than in girls (0.756 versus 0.425).

Table 6: Estimates of canonical correlations between the BIA characteristics and morphofunctional traits

Traits	*Boys*	*Girls*
Circumferences	0.766***	0.702***
Bone widths	0.647***	0.559**
Skinfolds	0.596***	0.569
Body diameters	0.649***	0.541*
Stature and body mass	0.614***	0.651***
BMI	0.608***	0.656***
Functional characteristics	0.756***	0.425
Sexual maturation indices	0.859***	0.476
Somatotypes	0.496***	0.315

* - < 0.05
** - < 0.01
*** - < 0.001

Presumably, hormonal changes in puberty have stronger effect on boys' somatotypes due to intensive growth of all three body components, particularly of muscles and skeletal growth.

Summarizing the results of multiple regression and canonical analysis, it can be concluded that the BIA characteristics are dependent on a great number of morphological and functional traits, which confirms their efficacy in assessment of morphofunctional status of the body, both in normal and pathological conditions (Nikolaev et al., 2004).

After the analysis of variations of BIA measurements, the second goal of the present study was to compare the body component estimates obtained by different methods. For BIA technique the prediction equations developed by Nikolaev (2001) gave the estimates of fat mass (FM-BIA) and fat-free mass (FFM-BIA) in the simplest two-components model. Using the anthropometric data fat mass (FM–anthro) and subcutaneous fat mass (SFM-anthro) were calculated (see the section "Materials and Methods").

In Table 7 the correlation coefficients for the estimates of different body components calculated by two methods are given. As could be assumed, the highest correlations are seen between different values of FM. Anthropometric estimates of fat mass and subcutaneous fat mass are connected with "functional" correlation, which can be explained by the presence of the same traits in the equations.

Table 8: Results of the regression analysis of FM-BIA by FM-anthro estimates

Regression coefficient	*Boys*	*Girls*
Intercept	-0.036	-0.064
SFM	0.781***	-10.349***
FM	0.026	11.189***
Multiple R	0.877	0.867
Multiple R^2	0.770	0.752
p	0.000	0.000

Similar results were obtained by the regression analysis of all three FM estimates (Table 8). R^2 values show that the level of consistency of the results obtained by both methods compiles 75-77%. Such figures can be considered quite satisfactory, that is they show that two methods – anthropometric and BIA – adequately estimate individual variations in the quantity of fat component in body mass.

Table 7: Correlation coefficients between different estimates of body components in boys and girls*

	1	*2*	*3*	*4*
1. FM-BIA	-	0.48	0.88	0.85
2. FFM-BIA	0.58	-	0.54	0.56
3. SFM–anthro	0.84	0.60	-	0.97
4. FM–anthro	0.85	0.61	1.0	-

*Correlation coefficients for boys are above diagonal, and for girls – below diagonal.

The correlation coefficients between FFM and all estimates of FM are high - 0.54 to 0.61 (Table 7). Theoretically the connections between characteristics determining each of the three body components should be close to zero (Tanner, 1988; Deryabin, 1986, 1990). Plausible explanation of this high value could be found in the fact that in the studied period of ontogenesis all body components are undergoing intensive growth which may be the reason for their close interconnections.

Age Changes of Body Composition Components

The age changes of BIA measurements and body composition components can be seen from Table 1 and Figures 3, 4.

In girls R_Z changes with age very little, which may mean the relative stability of fat component as a specific somatic trait of females. In boys there is a regular decrease of R_Z, which signifies the reduction of FM and the increase in FFM.

Changes of Z_C in boys and girls are similar: this measurement has a tendency to increase with age (Fig. 3).

Age changes in the estimates of body mass components are shown in Figure 4. FM in girls increases and remains almost stable in the age period between 15 and 17 years, while in boys there is a slight decrease in this parameter. FFM does not show much changes in girls, and demonstrates strong increase in boys, thus emphasizing the importance of fat-free component development in pubertal boys.

Body Mass Components and the Influence of Physical Activity

As was already mentioned in the section "Materials and methods" all children were divided into three groups according to their physical activity level: 1 – those who did not take part into regular physical exercise; 2 - those who took part

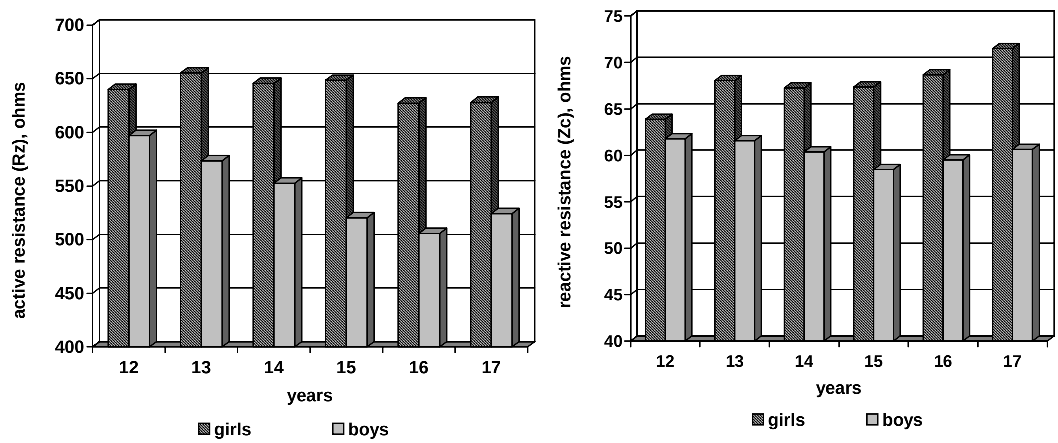

Fig. 3. Age changes of active resistance (R_Z) and reactive resistance, or reactance (Z_C)

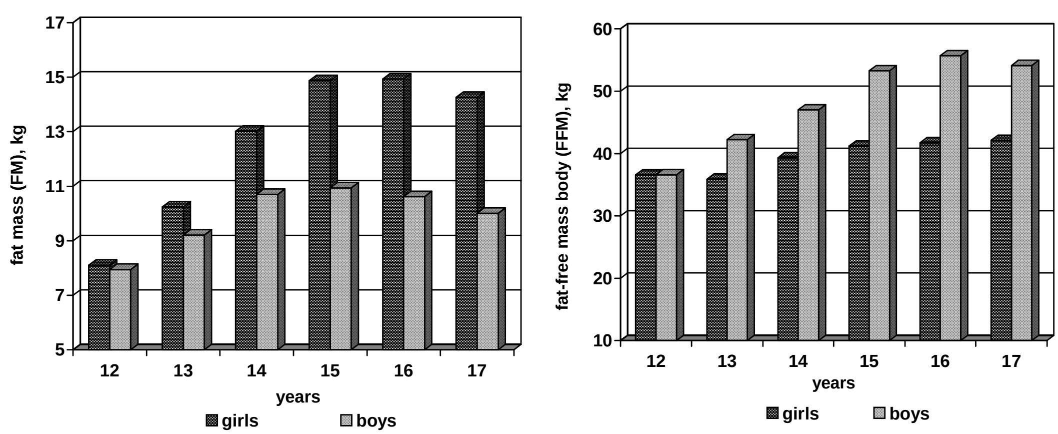

Fig. 4. Age changes of fat mass (FM-BIA) and fat-free mass (FFM-BIA)

in special sports programs in general education schools; 3 – students of special sports schools with high sports ranking.

The results of one-way ANOVA (Table 9) show that there are clear sex differences in the influence of physical activity on the structure of body mass components. In boys there are significant differences in R_Z and FFM-BIA estimates. It demonstrates again the role of muscles in the first place in the formation of male body shape.

In girls practically all estimates show significant effect of physical exercise. Only the FM calculated by BIA method remained independent from this factor. At the same time R_Z, which is supposed to be in direct proportion to the fat mass, has a highly significant connection with the level of physical activity. Such inconsistency of the results may be explained by non-adequacy of the prediction model calculated for children, and also by the fact that both impedance estimates are connected with all of

Table 9: Influence of physical activity level on the BIA measurements and body mass components in boys and girls (one-way ANOVA)

	Boys		*Girls*	
	F	*p*	*F*	*p*
SFM-anthro	0.195	0.823	3.883	0.022
FM-anthro	0.198	0.821	3.818	0.024
R_Z	17.700	0.000	9.689	0.000
Z_c	1.630	0.198	5.397	0.005
FM-BIA	1.171	0.312	2.399	0.094
FFM-BIA	10.027	0.000	5.584	0.005

body components. It should be also kept in mind that the sample size was rather limited, and even more so when all children were divided into three categories.

The ANOVA estimates the significance of influence of a selected factor (in our case – physical activity) to a trait taken separately. To assess the level of correlations between the physical activity status and the set of body mass components estimates the multiple regression analysis was performed (Table 10).

As can be seen from Table 10, the correlation between the level of physical activity, on the one hand, and BIA-measurements and body mass components estimates, on the other, is similar for both sexes but higher in boys. However there are some differences. Thus, in girls the coefficients characterizing the adipose tissue estimates calculated on anthropometric data, are much higher, which may be explained by the importance of fat component in the development of females typology. It may be also connected with different sports orientation in the groups of boys and girls with high sports ranking. Among girls there were a lot of swimmers, while in boys - football and hockey players.

Table 10: The results of multiple regression analysis between the level of sports qualification, BIA measurements and the estimates of body mass components

	Regression coefficients (b)	
	Boys	*Girls*
Intercept (B)	1.276	0.946
SFM-anthro	-0.477	-2.436
FM-anthro	0.445	2.366
R_Z	-0.359	-0.091
Z_C	0.279	-0.033
FM-BIA	-0.112	-0.161
FFM-BIA	0.182	0.202
Multiple R	0.546	0.407
Multiple R^2	0.298	0.166
p	0.000	0.000

The signs of regression coefficients reveal the contribution of each independent variable to the dependent variable – sports qualification. Z_C and FFM, which reflect muscle and skeletal development, are positively connected with the level of physical fitness. The negative coefficients of R_Z, FM-BIA and SFM-anthro also look logical in terms of physical fitness. The positive coefficients of FM-anthro estimates contradict to the idea of negative influence of body fat on sports activity. As the same tendency was discovered both for the boys and the girls it may be suggested that in the regression model the contribution of each parameter is estimated against another similar parameters. In our case the most important is the contribution of subcutaneous fat mass with maximal negative coefficients in both multiple regression equations.

As can be seen from Figure 5, in girls of the third group there is a distinctive decrease of FM-anthro and SFM-anthro estimates with increasing

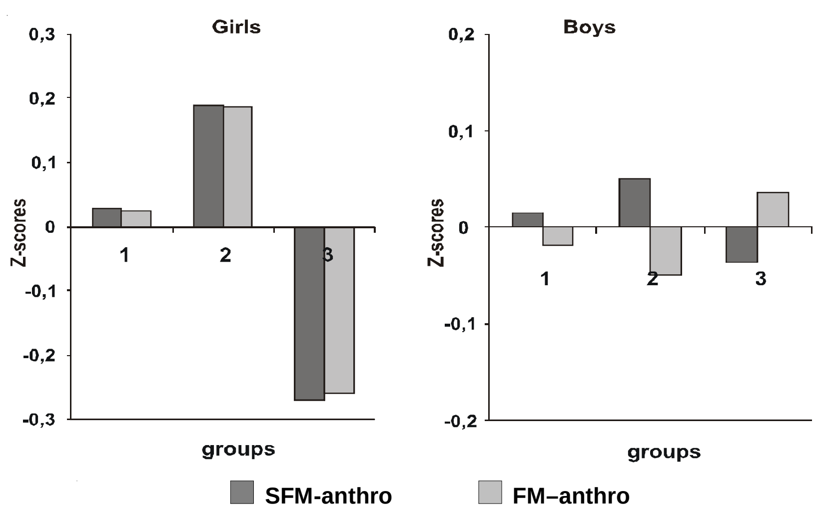

Fig. 5. The fat mass (FM–anthro) and subcutaneous fat mass (SFM-anthro) in groups of children with different level of physical activity (Z-scores)

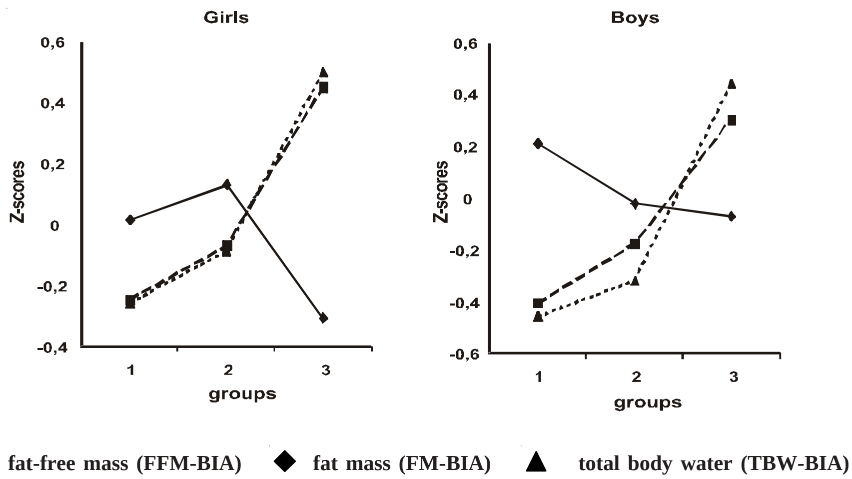

Fig. 6. Changes of body mass components estimated by BIA in groups of children with different level of physical activity (Z-scores)

level of physical activity. In boys such a tendency, though much less expressed is revealed only for subcutaneous fat mass.

More evident and highly significant differences between the three studied groups of children are revealed for BIA estimates – the three-component model. Among the adolescents with high degree of physical activity and sports ranking (3rd group) the contents of FFM and TBW are significantly increasing, and the FM is decreasing (Figure 6), which supports some previous investigations (Malina and Bouchard, 1991)

CONCLUSIONS

The results of the present study show that the estimates of FM and FFM obtained by BIA method are not the best ones as there is a high correlation between two body components, which are supposed to have an independent variability. It may be explained by intensive growth processes in children, which may cause the interconnected changes.

The estimates of fat components obtained by BIA and anthropometric methods are highly correlated both in boys and in girls: 0.85-0.88.

The multiple regression analysis between BIA estimates and anthropometric and functional traits revealed a higher level of correlation in boys than in girls with the exception of skinfolds, which may reflect the importance of adipose tissue for the development of typical somatic characteristics in girls during puberty.

The stepwise regression analysis selected a number of morphofunctional characteristics influencing the BIA measurements. There are some differences in these sets: besides anthropometric traits, sexual maturation indices are included in boys and functional parameters in girls.

The age changes of BIA measurements reflect specific trends in the development of those components, which define the typical somatic characteristics for both sexes.

The degree of physical activity has a strong effect on body components: the contents of FFM and TBW are significantly increasing, and the FM is decreasing.

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KEYWORDS Body composition, auxology, Moscow adolescents, anthropometry, bioelectrical impedance analysis

ABSTRACT 195 girls and 259 boys of Russian ethnicity from 12 to 17 years old were investigated cross-sectionally in 2005 in different Moscow schools. According to the level of physical activity they were divided into three groups: 1 – those who did not take part into regular physical exercise (44 boys and 50 girls); 2 - those who took part in special sports programs in general education schools (82 boys and 82 girls); 3 – students of special sports schools with high sports ranking (133 boys and 63 girls). The program included anthropometric measurements, evaluation of sexual maturation indices, somatotypes, "functional" traits (blood pressure, pulse rate, hand grip, etc). For the study of body composition the bioelectrical impedance analysis (BIA) was used. The estimates of body components were calculated by anthropometric and BIA methods. For fat components these estimates are highly correlated both in boys and in girls and equal 0.85-0.88 correspondingly. Age changes of BIA measurements and body components were analysed. With multiple regression analysis it was shown that BIA measurements are dependent on a great number of morphological and functional traits, with the most informative sets of traits being selected. The degree of physical activity has a strong effect on body components: the contents of FFM and TBW are significantly increasing, and the FM is decreasing.

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