Bioelectric Impedance Phase Angle and Body Composition in Russian Children Aged 10–16 Years: Reference Values and Correlations

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Abstract

We describe the results of anthropological study of healthy Russian children which included both anthropometry and bioimpedance analysis of body composition (n=946). The whole-body impedance was measured according to a conventional tetrapolar scheme using BIA analyzer ABC-01 “Medass” (SRC Medass, Russia). We report a normal ranges for phase angle and BIA body composition parameters, such as absolute and relative contents of fat (FM, %FM) and fat-free mass (FFM) for boys and girls depending on age. FFM was assessed using Houtkooper equation. The obtained estimates of body composition were compared with those derived from skinfold anthropometry using Slaughter, Deurenberg, Matiegka, and other equations. Also, the results of correlation and factor analysis of phase angle and BIA body composition with various anthropometric indexes are discussed.

Keywords: phase angle, body composition, children

1. Introduction

Bioelectrical impedance analysis is a noninvasive and portable method widely used in health-related studies. Along with indirect estimates of body composition relying upon population-specific equations, there is growing interest for direct use of BIA reactance and resistance measurements in epidemiological and clinical investigations [1, 2]. Phase angle, which is calculated as an arc tangent of the reactance to resistance ratio multiplied by a constant to convert radians to degrees [3, 4], was shown to be a useful nutritional indicator in children [5] and a significant prognostic factor of clinical outcome in various conditions such as liver cirrhosis, AIDS, and critical illness [2, 6].

There are many reports concerning measurements of phase angle and BIA body composition in children from a number of countries and study groups [6-8]. The aim of this study was to describe population reference values of phase angle and BIA body composition in Russian children aged 10–16 years and to compare the obtained estimates with various anthropometric predictions.

2. Materials and methods

Anthropometry was performed in the 946 children (500 boys and 446 girls) aged 10–16 years using standard measurement procedures described in [9-11]. The data were collected cross-sectionally in Moscow schools in 2005. Skinfold thicknesses were measured in 294 males and 140 females (of the 946) by the Lange caliper on the right side of the body under standard pressure (10 g/mm^2). Body composition parameters were evaluated using Slaughter (S1, S2), Deurenberg (DR), Matiegka (M), and Dezenberg (D1, D2) equations (Table 2). Body density (BD) was converted into percent fat mass (%FM) using Siri equation %FM = $(C_1/BD - C_2)\times 100$ with the coefficients C_1 and C_2 depending on age and sex [12]. The whole-body impedance was measured on the right side of the body by the BIA analyzer ABC-01 “Medass” (SRC Medass, Russia) according to a conventional tetrapolar scheme at a constant frequency 50 kHz. Phase angle (PA) was calculated as arctan $(X_C/R)\times 180°/\pi$, where X_C is the reactance and R the whole-body electric resistance. Fat-free mass (FFM) was assessed using Houtkooper equation [20] which was validated against 3C model of body composition and is currently recommended for use in children [19]: FFM = 0.61 × (Height^2/R) + 0.25 × BM + 1.31, where Height is standing height (m), and BM – body mass (kg). Fat mass was calculated as the difference between BM and FFM, and %FM as (FM/BM)×100.

Pairwise comparison was used to compare estimates of percentage fat using Houtkooper and SKF equations. A value of 0.05 was used to define significance. All statistical analyses were performed by using Statistica software (ver.6.0).

Table 1. Height, Weight, and BMI of the Study Group According to Age and Sex, Mean (SD)

Age	n	Height, cm	Weight, kg	BMI, kg/m^2
Boys				
10	52	143.0 (6.3)	37.9 (9.3)	18.4 (3.4)
11	65	147.9 (6.8)	42.0 (9.8)	19.1 (3.4)
12	68	155.2 (7.9)	47.8 (10.6)	19.8 (4.1)
13	82	163.5 (9.2)	53.9 (13.2)	20.0 (3.5)
14	85	169.1 (9.2)	59.4 (11.8)	20.6 (2.8)
15	76	173.1 (8.3)	63.0 (13.3)	20.9 (3.1)
16	72	176.9 (6.8)	67.0 (11.1)	21.4 (3.0)
Girls				
10	41	141.2 (7.0)	33.9 (7.1)	17.0 (3.4)
11	42	148.4 (8.9)	39.2 (9.9)	17.6 (3.0)
12	66	155.2 (8.5)	45.6 (9.8)	18.8 (3.0)
13	81	158.0 (8.8)	49.0 (8.1)	19.8 (4.0)
14	75	161.3 (5.9)	52.1 (10.7)	20.0 (3.4)
15	85	163.2 (5.6)	56.9 (9.8)	21.3 (3.3)
16	56	164.1 (5.6)	57.0 (8.1)	21.1 (2.8)

Table 2. Anthropometric Prediction Equations for %FM, FM, and Body Density in Children

	Ref	SKF	Equation
SL1	[13]	2	%FM = 0.735 × S1 + 1.0 (boys)
		2	%FM = 0.610 × S1 + 5.1 (girls)
SL2	[13]	2	%FM = 0.783 × S2 + 1.6 (boys)
		2	%FM = 0.546 × S2 + 9.7 (girls)
DR	[14]	4	BD = 1.1133 – 0.0561×lgS3+1.7×Age×10^{-3} (boys)
		4	BD = 1.1187 – 0.0630×lgS3+1.9×Age×10^{-3} (girls)
M	[15]	8(7)	FM (kg) = 1.3 × d × S
D1	[16]	1	BF (kg) = 0.38 × BM (kg) + 0.30 × TS (mm) + 0.87 × Sex – 8.61, where Sex = 1(boys), 2(girls)
D2	[16]	0	BF (kg) = 0.56 × BM (kg) –8.17

SKF – the number of skinfolds measured, S1 – the sum of the triceps and calf skinfold thicknesses (mm), S2 – the sum of the triceps and subscapular skinfold thicknesses (mm), lgS3 – decimal logarithm of the sum of the biceps, triceps, subscapular, and suprailiac skinfold thicknesses (mm), TS – the triceps skinfold thickness, d – average thickness of subcutaneous fat layer (mm) measured at 8 and 7 sites in boys and girls, respectively, according to the scheme by Lutovinova et al [17], and S body surface (m^2) [18].

3. Results and discussion

Tables 3 and 4 show bioelectric parameters and body composition estimates for our group of children according to age and sex. Along with the gradual age-related increasing of height, weight, and body mass index (see Table 1), we observed the same patterns for FFM and FM (Table 4). In males, the resistance decreased significantly across age groups from 651.1 (10 years) to 501.8 Ohms (16 years). The similar trend can be seen in the females’ data with the exception of a local maximum for R at the age of 14 years. The reactance decreased up to 14 and 13 years in boys and girls with the slight and moderate increase thereafter, respectively. In boys, one can see a decline in the percentage fat mass between 11 and 15 years, with an opposite regularity in girls. In both sexes, height and weight were better predictors for fat-free mass, and body mass index – for fat mass (Table 5).

In boys and girls, phase angle increased with an increase in weight, BMI, FFM and TBW. Figure 1 illustrates significant relationship of PA with FFM in boys. Phase angle was significantly inversely associated with the percentage fat in boys (see Table 5) and with the percentage fat-free mass in girls. There was no association between the phase angle and absolute fat mass in boys, as well as between the phase angle and height in girls.

Table 3. Resistance, Reactance, Phase Angle, and Total Body Water of the Study Group According to Age and Sex, Mean (SD)

Age	n	R, Ω	X_C, Ω	PA	TBW, L
Boys					
10	52	651.1 (59.3)	71.8 (7.3)	6.3 (0.6)	23.3 (3.9)
11	65	625.4 (65.7)	69.3 (7.6)	6.3 (0.5)	26.7 (4.1)
12	68	581.9 (71.8)	64.4 (9.8)	6.3 (0.7)	31.2 (4.5)
13	82	555.0 (79.7)	62.3 (7.9)	6.4 (0.6)	35.6 (5.9)
14	85	531.4 (69.5)	61.1 (7.7)	6.6 (0.8)	38.6 (5.9)
15	76	511.5 (56.2)	61.2 (8.2)	6.8 (0.8)	41.0 (5.5)
16	72	501.8 (56.4)	61.2 (6.9)	7.0 (0.8)	42.8 (5.0)
Girls					
10	41	725.0 (89.3)	78.2 (8.7)	6.2 (0.5)	20.7 (3.3)
11	42	667.5 (74.0)	71.9 (9.6)	6.2 (0.5)	24.3 (4.2)
12	66	641.2 (68.8)	67.6 (8.0)	6.0 (0.6)	27.2 (4.1)
13	81	631.1 (66.0)	67.4 (6.6)	6.1 (0.6)	28.3 (3.5)
14	75	637.9 (67.6)	69.9 (7.0)	6.3 (0.5)	29.2 (4.0)
15	85	620.9 (62.5)	69.9 (7.4)	6.4 (0.6)	30.9 (3.5)
16	56	607.4 (64.6)	70.0 (8.3)	6.6 (0.6)	31.4 (2.9)

Table 4. Absolute and Relative Fat Mass, and Fat-Free Mass of the Study Group as Accessed by BIA According to Age and Sex, Mean (SD)

Age	n	FM, kg	%FM	FFM, kg	FFM, kg [8]
Boys					
10	52	7.8 (5.3)	18.8 (8.0)	30.2 (4.9)	31.1 (4.1)
11	65	8.5 (5.4)	19.1 (7.1)	33.4 (5.4)	33.8 (4.3)
12	68	8.7 (6.1)	17.2 (8.1)	39.1 (6.8)	36.6 (4.6)
13	82	8.9 (6.4)	15.8 (6.6)	45.0 (9.2)	40.7 (4.9)
14	85	9.6 (5.2)	15.7 (6.1)	49.8 (9.2)	49.5 (5.2)
15	76	9.6 (6.0)	14.5 (5.6)	53.3 (8.8)	55.5 (5.5)
16	72	10.4 (5.1)	15.0 (5.4)	56.6 (7.6)	58.0 (5.8)
Girls					
10	41	7.0 (4.0)	19.6 (8.0)	26.9 (4.4)	29.3 (3.4)
11	42	7.5 (4.6)	17.9 (7.7)	31.7 (6.5)	32.8 (3.6)
12	66	9.6 (4.6)	20.1 (5.8)	36.0 (6.2)	36.1 (3.8)
13	81	11.1 (4.3)	22.0 (5.7)	38.0 (5.1)	38.7 (4.0)
14	75	12.6 (5.6)	23.3 (5.7)	39.5 (5.9)	40.5 (4.1)
15	85	14.9 (5.4)	25.6 (5.1)	42.0 (5.5)	41.7 (4.3)
16	56	14.1 (4.5)	24.3 (4.9)	42.9 (4.7)	42.6 (4.5)

Table 5. Correlations of Phase Angle and BIA Body Composition with Height, Weight, and BMI

	PA	FM	%FM	FFM	TBW
	Boys (n=500)				
Ht	0.24	0.26	0.16	0.91	0.91
Wt	0.29	0.69	0.27	0.94	0.92
BMI	0.24	0.85	0.59	0.63	0.59
PA	•	N.S.	0.14	0.37	0.35
	Girls (n=446)				
Ht	N.S.	0.46	0.25	0.81	0.80
Wt	0.28	0.90	0.68	0.94	0.92
BMI	0.32	0.89	0.77	0.69	0.66
PA	•	0.22	0.13	0.29	0.27

Figure 1. The relationship between phase angle and fat-free mass in boys

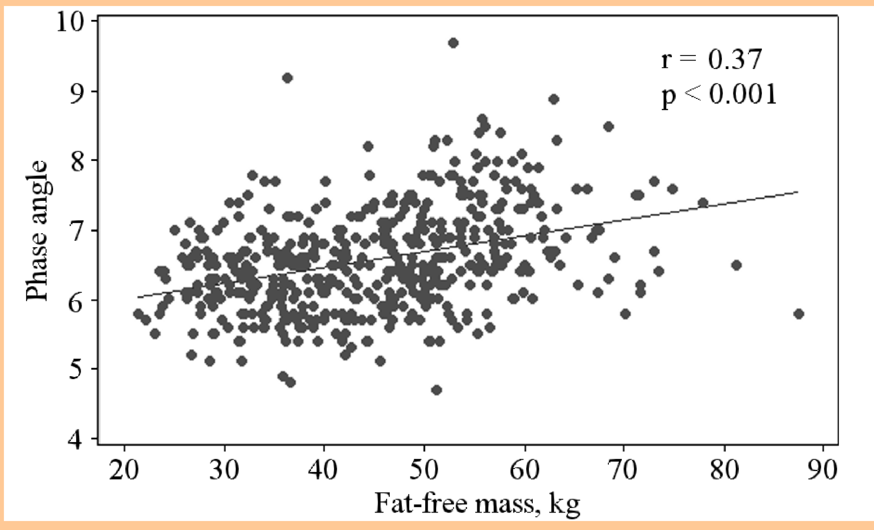

Table 6. Results of Factor Analysis of Phase Angle with Selected Anthropometric and Body Composition Variables

	Boys		Girls	
Variable	Factor 1	Factor 2	Factor 1	Factor 2
PA	0.171	0.044	0.084	–0.063
Ht	0.991	0.021	0.133	–0.989
Wt	0.849	–0.401	0.564	–0.658
BMI	0.403	–0.673	0.700	–0.167
FM	0.308	–0.921	0.852	–0.363
%FM	–0.134	–0.982	0.985	–0.123
FFM	0.931	–0.064	0.271	–0.793
Proportion of variance	0.411	0.347	0.372	0.317

Figure 2. Comparison of predicted %FM between Slaughter (S1) and Houtkooper (H) equations in girls. Solid line represents the mean difference between methods

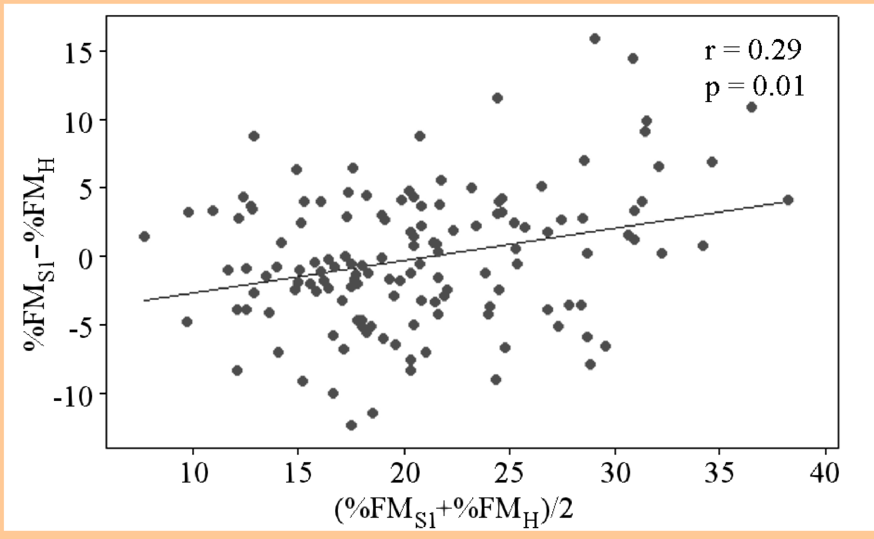

Table 7. Correlations between Anthropometric and BIA Estimates of FM in Boys and Girls (Upper and Lower Parts of the Table, Respectively)

	H	DR	D1	D2	M	SL1	SL2
H	•	0.98	0.78	0.67	0.83	0.86	0.87
DR	0.99	•	0.88	0.80	0.79	0.88	0.88
D1	0.93	0.96	•	0.97	0.64	0.82	0.79
D2	0.91	0.94	0.97	•	0.45	0.67	0.64
M	0.82	0.80	0.83	0.72	•	0.91	0.93
SL1	0.89	0.90	0.93	0.83	0.91	•	0.97
SL2	0.89	0.90	0.92	0.82	0.92	0.99	•

The results of BIA estimates of the mean values of FFM and %FM are very similar to the data on white Dutch children [8] obtained using dual-energy X-ray absorptiometry (for FFM comparison, see the last two columns in Table 4). One can note, however, the greater values of SDs for FFM across age groups in our study, probably, reflecting higher inhomogeneity of the population of Russian children in relation to body composition. A principal component (factor) analysis of phase angle with selected anthropometric and body composition variables with varimax rotation was used to obtain a set of independent uncorrelated factors (Table 6). The analysis returned two factors which explained 75.8% and 68.9% of the total variance in boys and girls, respectively.

In boys, Factor 1 accounted for 41.1% of the total variance and had maximal loadings of height, weight, and FFM, reflecting a principal role of *skeletal and muscular traits* in their somatic development. Factor 2 (`adiposity’) had maximal (absolute) loadings of %FM, FM, and BMI. In girls, the above factors followed in the reverse order suggesting primary importance of *adiposity traits* (37.2% of the total variance).

Correlations between BIA and skinfold anthropometry estimates of FM were significant ranging between 0.67 and 0.98 (Table 7). The least value was obtained in boys for ‘purely’ anthropometric equation D2 not relying upon skinfold data (see Table 2).

To test if these strong relationships does in fact indicate the agreement between the measurement techniques (for discussion, see [21]), we calculated the differences between the anthropometric and BIA estimates of fat mass (FM_{anthro}-FM_{BIA}). The obtained mean values for the combined group of males were 0.5, 0.8, 1.1, 2.5, 7.4, and 15.1 kg for Matiegka (M), Slaughter (S2, S1), Deurenberg (DR), and Dezenberg (D1, D2) equations, respectively. In terms of the percentage fat mass, the mean (SD) scores for males obtained from H, S1, S2, DR and M equations were 15.8% (5.7), 17.5% (7.6), 16.9% (7.4), 20.4% (4.2), and 15.9% (7.8) respectively. The paired sample *t*-test showed that only Matiegka equation had no significant difference with the results of BIA estimates of the %FM. In females, the mean %FM scores obtained from the aforementioned equations, were 20.7% (5.9), 20.6% (7.2), 19.9% (7.1), 25.1% (3.8), and 20.4% (6.7) respectively. The differences between BIA and skinfold anthropometric estimates S1, M, and S2 were insignificant. So, of the anthropometric methods, the best agreement with the results of BIA estimates of the mean %FM was obtained using Matiegka and Slaughter equations. For our study group, Dezenberg equations were inappropriate in both genders.

4. Conclusion

In this work, we represent the mean values and standard deviations for phase angle and body composition in the 946 Russian children aged 10–16 years according to age and sex. These data can serve as a reference for use in outpatient and clinical practice. Of the anthropometric methods, Matiegka equation in males, as well as S1, M, and S2 equations in females, showed an agreement with BIA estimates of percentage fat mass, but had a significant unidirectional biases with respect to relative fatness.

Since all the equations used in this study for body composition analysis assume constant density of fat-free mass which is known to vary significantly across age, more work has to be done for the validation of these formulae in Russian children against reference models and methods.

5. References

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