ACTA MEDICA LITUANICA. 2008. Vol. 15. No. 1. P. 39–42

Assessment of body composition of young female adults using anthropometry and bioelectric impedance analysis

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Background. Body composition correlates directly with the continuum of health, ranging from mortality and morbidity to immunity, longevity, high function and athletic performance. The aim of the study was to compare the body composition studied by anthropometrical methods and by BIA and to get reference values data for different parameters describing body composition in young Slovene women.

Material and methods. Body composition of a group of 34 female adult soldiers of the Slovenian army was analyzed by using, for the first time in Slovenia, Soft Tissue Analyzer / Body Impedance Analyzer (STA / BIA) (Akern, Italy). At the same time, two-compartment body composition analysis was performed using anthropometry.

Results. Our results revealed strong correlation (r = 0.88) between anthropometrically determined body composition (mean estimated fat % = 25.18%) and body composition determined by bioelectrical impedance analysis (mean estimated fat % = 28.5%). The mean values of phase angle were 6.35°. Some comparisons with similar groups were done, and the results showed that our group had a higher amount of fat mass.

Conclusions. High correlation was found between the elements of body composition analysed by both anthropometrical and BIA methods. Both methods are precise and suitable for the analysis of body composition. More studies among such groups are recommended.

Key words: body composition, anthropometry, STA / BIA, young female adults

INTRODUCTION

Analysis of body composition has a long history at our Department. Our outstanding anthropologist Prof. Dr. Božo Škerlj was the founder of the Slovenian physical anthropology and of the Department in 1946. One of his main scientific research fields was body composition and constitution, mainly of the female body. In 1959, he published a well known methodology of describing human physique on the basis of four aspects or four vectors continuum, nowadays still well known. One of them was the aspect to assess the amount of soft tissue and the other, the distribution of subcutaneous fat tissue in human body. The other two deal with the assessment of sex expression and type of body constitution (1, 2). Later anthropometry was used for determining body composition applying the method of two compartment analyses and anthropometrical method of five-way fractionation of body mass (3–6). Nowadays we analyse body composition also by using different bioelectrical impedance analyzers (7–12).

The importance of body composition research is in the fact that body composition correlates directly with the continuum of health, ranging from mortality and morbidity to immunity, longevity, high function and athletic performance. The data on body composition is useful information about an individual's health. Very important indices are the amount of water, the amount of muscle mass, and the amount of body fat, the most often analyzed component. Numerous health problems are connected with the amount of fat. A high trend of overweight people is found all over the word, but, on the other hand, there are problems associated with underweight and too low amount of fat. Therefore, the purpose of body composition analysis is to assess and improve the function, help maintaining the function, productivity, immunity, physical performance and longevity.

The aim of our research was to find the elements of body composition in a sample of healthy young adult female group.

We used the method of anthropometry and measurements by the STA / BIA machine. We verified the degree of correlation between the results of both methods and compared our results with the results of similar groups. However, first of all, we planned to get reference values and range values for the parameters of the body composition done by Soft Tissue Analyzer and to look for the diversity of Akern BIA Vector Nomograms in hydration state and phase angle.

MATERIALS AND METHODS

Healthy adult female members of Slovenian army were recruited in 2005. The measurements were part of NATO Project Science for Peace and Security conducted by Prof. Dr. Igor Mekjavic

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from the Institute Josef Stefan Ljubljana. Altogether, 432 people of both sexes were measured. Only 34 females passed the anthropometrical measurements and measurements by the Soft Tissue Analyzer. Mean age was 24.8 (minimum value 18 years and maximum value 31 years). All the subjects showed their cooperation by signing an agreement. Permission to conduct the study was also obtained from the Commission of Medical Ethics of the Ministry of Health of the Republic of Slovenia.

Measurements were done in the morning only at the Institute Josef Stefan in Ljubljana and in the House of Mariner in Ankaran by well-trained people. The place was warm and bright. Based on standard methods and done by standard instruments (13–15), 30 parameters were measured. For the purpose of this analysis we chose stature, weight, skinfold sites on triceps, subscapular, suprailiacal, horizontal abdomen, medial thigh and medial calf. For the need of two-compartment analysis of the body composition we calculated body density based on prediction formula after Jackson and Pollock (1980, jp80):

BD jp80 = 1.0994921 – 0.000994921 × (SFTri + SFSupil + SFThi) + 0.0000023 × (SFTri + SFSupil + SFThi)2 – 0.0001392 × AGE,

where *BD* is body density, *SFTri* is skinfold on triceps (mm), *SFSupil* is skinfold on suprailiacal site (mm), *SFThi* is skinfold on medium thigh (mm), *AGE* is age in years.

Taking body density we calculated fat percentage using Siri1 which is most commonly used and by modified Siri2 according to the recommendation of Heyward and Stolarczyk (14):

%BF Siri1 = (4.95/BD – 4.50) × 100; %BF Siri2 = (5.01/BD – 4.57) × 100.

Then we calculated fat mass (FM) and fat free mass (FFM) according to the following formulas: FM (kg) = (%BF / 100) × weight in kg; FFM (kg) = weight (kg) – FM (kg). All those formulas are suitable for adult Caucasian population.

Bioelectrical impedance analysis was carried out using Soft Tissue Analyser / Body Impedance Analyzer – STA/BIA (Akern Bioresearch, Italy). Impedance analysis was performed applying classic tetra polar technique, using sinusoidal current injection at the fixed frequency of 50 kHz. The subject had to lie at least five minutes because of the distribution of all body fluids. The positioning of the subject and electrodes had to be obtained very carefully. They were not allowed to drink alcohol, coffee and tea for 48 hours before the measurements, two hours prior to the measurements they were not allowed to eat, they visited toilet, they were not in the menstrual cycle and they did not wear any metal jewellery (16).

In BodyGram 1.3 we had to inscribe stature, body mass, sex and age of the subject measured. Fig 1 shows a case of BodyGram – a qualitative and quantitative body composition analysis. STA / BIA measured resistance and reactance and phase angle. Computer program presented the results in a form of a report in which the following compartments were calculated: body cell mass (BCM), total body water (TBW), extracellular water (ECW), intracellular water (ICW), fat mass (FM), fat free mass (FFM), muscle mass (MM), basal metabolic rate (BMR), body mass index (BMI) and body cell mass index (BCMI). Nomogram BIAVECTOR showed the physiological state of the subject in a special graphical form. The Nomogram, shown in the elliptical form, was composed of three areas: confidence (50%), tolerance (75%) and abnormality (95%). The Nomogram was divided by sloping horizontal and sloping vertical lines to the zones of dehydration, malnutrition, fluid overload and good nutrition (16) (Figure). Our results were compared with the group of female students from Slovenia (8) and a group of Swiss adult females (17, 18). The results were analysed by standard statistical methods in Microsoft Excell, Student's t-test and Pearson's correlations coefficient (19).

RESULTS

Table 1 presents basic statistical parameters for anthropometrical measurements.

The mean age of females was 24.82. The mean stature was 168.35 cm and weight 62.47 kg. Slovene female students with mean age of 22 years have mean stature 167.72 cm and weight 60.37 kg (8).

Table 2 presents basic statistics of calculated two-compartment body composition parameters. The amount of fat was 25.18% using Jackson and Pollock's formula and calculated by Siri1, and in the student group calculated by the same formulas 22.20% (1% risk considered to be significant). Fat percentage using Siri2 was 23.94% (1% risk considered to be significant). Mean BMI was 22.04 in a range from 18.32 to 33.63.

Table 3 presents the results of measurements and calculation done by the STA / BIA machine.

Table 1. **Anthropometric characteristics of Slovene female group**

Parameter	N	min	Max	R	X	SEx	SD	SESD	KV%	SEKV%
Age (years)	34	18	31	13	24.82	0.57	3.34	0.41	13.47	2.31
Stature (cm)	34	154.9	180.20	25.30	168.35	1.03	6.03	0.73	3.58	0.61
Weight (kg)	34	47.50	89.90	42.40	62.47	1.39	8.10	0.98	12.96	2.22
Triceps skinfold (mm)	34	8.80	32.40	23.60	17.67	0.92	5.36	0.65	30.33	5.20
Subscapular skinfold (mm)	34	6.60	31.20	24.60	13.59	0.91	5.33	0.65	39.22	6.73
Suprailiacal skinfold (mm)	34	6.40	33.20	26.80	19.45	1.20	6.99	0.85	35.96	6.17
Abdominal skinfold (mm)	34	7.80	33.00	25.20	16.39	1.03	6.00	0.73	36.59	6.28
Medial thigh skinfpld (mm)	34	10.80	45.00	34.20	28.09	1.47	8.59	1.04	30.56	5.24
Medial calf skinfold (mm)	34	6.80	27.20	20.40	15.35	0.99	5.79	0.70	37.72	6.47

Table 2. **Two-compartment body composition parameters**

Parameter	N	Min	Max	R	X	SEx	SD	SESD	KV%	SEKV%
BDjp80 (g/cm^3)	34	1.0168	1.0713	0.0545	1.0419	0.0022	0.0130	0.0016	1.2472	0.2139
%BF Siri1	34	12.06	36.84	24.78	25.18	1.01	5.91	0.72	23.46	4.02
FM Siri1 (kg)	34	5.73	33.12	27.39	16.01	0.92	5.36	0.65	33.46	5.74
FFM Siri1 (kg)	34	37.16	56.78	19.62	46.46	0.79	4.62	0.56	9.94	1.71
%FFM Siri1	34	63.16	87.94	24.78	74.82	1.01	5.91	0.72	7.90	1.35
%BF Siri2	34	10.66	35.74	25.08	23.94	1.03	5.98	0.73	24.97	4.28
FM Siri2 (kg)	34	5.06	32.13	27.07	15.24	0.91	5.32	0.64	34.89	5.98
FFM Siri2 (kg)	34	37.78	57.77	19.98	47.24	0.81	4.70	0.57	9.95	1.71
%FFM Siri2	34	64.26	89.34	25.08	76.06	1.03	5.98	0.73	7.86	1.35
BMI (kg/m^2)	34	18.32	33.63	15.31	22.04	0.46	2.65	0.32	12.04	2.06

Table 3. **Parameters calculated by Bodygram®**

Parameter	N	min	max	R	X	SEx	SD	SESD	KV%	SEKV%
RZ (Ohm)	34	492	898	406	592.82	13.18	76.85	9.32	12.96	2.22
XC (Ohm)	34	51	90	39	65.88	1.49	8.71	1.06	13.22	2.27
PA (o)	34	5.3	7.2	1.9	6.35	0.08	0.47	0.06	7.37	1.26
FM BIA (kg)	34	8.90	45.30	36.40	18.15	1.11	6.48	0.79	35.69	6.12
%FM BIA	34	17.00	50.40	33.40	28.50	1.04	6.09	0.74	21.36	3.66
FFM BIA (kg)	34	37.60	51.10	13.50	44.24	0.60	3.47	0.42	7.85	1.35
%FFM BIA	34	49.60	83.00	33.40	71.50	1.04	6.09	0.74	8.51	1.46
MM BIA (kg)	34	22.10	30.40	8.30	25.91	0.36	2.12	0.26	8.19	1.40
%MM BIA	34	30.00	47.10	17.10	41.87	0.57	3.30	0.40	7.88	1.35
TBW BIA (l)	34	27.60	38.80	11.20	33.43	0.50	2.90	0.35	8.67	1.49
%TBW BIA	34	40.10	61.50	21.40	53.93	0.69	4.01	0.49	7.43	1.28
BCM BIA (kg)	34	17.90	24.60	6.70	20.91	0.29	1.71	0.21	8.16	1.40
%BCM BIA	34	44.00	49.40	5.40	47.29	0.21	1.20	0.15	2.54	0.44

The mean value for the predicted fat mass calculated by STA / BIA was 18.15 ± 6.48 kg, the mean value of fat mass with Siri1 16.01 ± 5.36 kg and with Siri2 15.24 ± 5.32 kg. Pearson's correlation coefficient was between STA / BIA and Siri1 r = 0.88, between STA / BIA and Siri2 r = 0.87 and between Siri1 and Siri2 r = 1.00. All those high values show that the methods are positively correlated.

The normal phase angle ranges of health controls are between 6 and 8 degrees. In our group, the mean values of phase angle were 6.35 degrees ±0.47. Student population has RZ, % fat, kg fat measured by BIA significantly smaller ($p < 0.001$).

DISCUSSION

Zerbo-Šporin (8) in her doctoral thesis confirmed that Jackson-Pollock's regression formula which we applied to calculate the body density from skinfolds on triceps, suprailiacal, thigh and age was the most suitable for determining the body composition of females in early adulthood period. Prediction error of density using this formula is only 0.8% and it highly correlates with the density determined by underwater weighing (r = 0.915) (7). The mean value of fat percentage was 25.18% (Siri1) and 23.94% (Siri2). Heyward and Stolarczyk (12) recommend 23% fat for female groups. Our group had higher value. After their categorization they belonged to a group over the recommended one (24–31%). Results of anthropometrical measurements of female soldiers from USA 17–22 years of age (mean stature = 164.1 cm and weight = 55.8 kg) shows mean value for % fat of 28.7% (18). High correlation was found between the sum of skinfolds and body fat (r = 0.997).

Our females had 28.5% of body fat measured by STA / BIA which is also higher than the recommended values.

Quoted by the producer Akern (16), the recommended value for females under 30 years of age is between 16–20%. What is the reason for the results? This group had relatively orderly nutrition diet and enough physical activity. The increase might be due to the general trend of bigger fatness in the entire world.

The mean value of BMI was 22.04 ± 2.65. Body mass and BMI are not good indicators of changes in the amount of fat and fat free mass (17, 18). Tallury (20) suggests substituting BMI as an indicator of nutritional state by body cell mass index (BCMI). This index is defined as body cell mass in kg/stature in m^2. BIA method and phase angle have been reported as a prognostic tool in various clinical situations, such as renal disease, pulmonary tuberculosis, cancer, HIV (21).

Relatively little is known about reference values of phase angle in healthy population. Barbosa-Silva and co-authors (21) conducted a study on 1967 healthy adults to understand the relation between phase angle and such variables as sex, age and body-composition. In their study phase angle of female was 6.53° ± 1.01°.

In 2004, Buffa and co-authors measured population in Sardinia, in a group of 101 females between 20 and 30 years, and found the mean value of phase angle 6.5° (22). Bosy-Westphal (23) analysed a large sample of healthy German population. The use of specific population and probable impedance analyzer specific reference values of phase angle is recommended.

We compared our results with the results of Slovene students (8) and Swiss females (17). Our females were significantly higher than the Swiss group, and the same difference was observed in weight. Fat percentage measured in all the three groups by BIA showed higher values in our group. Because our group was older this could be also the reason for such a result.

CONCLUSIONS

High correlation was found between the elements of body composition analysed applying both anthropometrical and BIA methods. Both methods are precise and suitable for the analysis of body composition. The results produced by STA / BIA analyzer provided us with the basic information concerning the means and ranges of all the calculated parameters. Thus, we have acquired a lot of information for further studies.

Our group of females has higher values of fat mass compared to other suitable groups; therefore, we recommend more studies of body composition among such groups.

Received 27 November 2007
Accepted 6 February 2008

References

1. Škerlj B. Splošna antropologija v osnovnih potezah. 2 izdaja. Ljubljana: Državna založba Slovenije; 1959: 80–99.
2. Škerlj B. Towards a systematic morphology of human body. Acta Anatomica1959; 39: 220–43.
3. Tomazo-Ravnik T. Sestava telesa in človekov somatotip v juvenilnem obdobju. Doktorska disertacija. Ljubljana: Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za biologijo; 1994: 227.
4. Tomazo-Ravnik T. Sestava človeškega telesa v juvenilnem obdobju. Zdravstveni vestnik 1996; 65: 443–5.
5. Tomazo-Ravnik T. Studies of body composition in Slovenia. Collegium Antropologicum 1998; 22(2): 403–9.
6. Štefančič M, Tomazo-Ravnik T. A longitudinal observation of growth and body composition in a sample of 10 to 14-year-old children from Ljubljana, Slovenia. Acta medica Auxologica 1998; 30: 161–7.
7. Zerbo-Šporin D, Štefančič M. 2004. Body fatness and fat distribution in female university students. European Anthropological Association. Biennial books of EAA 2004; 3: 121–30.
8. Zerbo-Šporin D. Izpeljava antropometrijske metode razporeditve podkožnega maščevja in sestava telesa pri dekletih v zgodnji adultni dobi. Doktorska disertacija. Ljubljana: Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za biologijo; 2002: 125.
9. Praprotnik M. Analiza sestave telesa vzorca odrasle moške populacije z metodo bioelektrične impedance in antropometrijo. Diplomsko delo. Ljubljana: Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za biologijo; 2006: 84.
10. Sirc A. Ocenjevanje deleža maščobnega tkiva v telesu pri odraslih, s pomočjo merjenja debelin kožnih gub in bioelektrične impedance. Diplomsko delo. Ljubljana: Oddelek za fizioterapijo, Visoka šola za zdravstvo, Univerza v Ljubljani; 2006: 48.
11. Jezernik D. Analiza sestave telesa vzorca odrasle ženske populacije z antropometrijo in metodo merjenja bioelektrične prevodnosti. Diplomsko delo. Ljubljana: Univerza v Ljubljani, Biotehniška fakulteta, oddelek za biologijo; 2007: 77.
12. Tomazo-Ravnik T, Jakopič V. Changes in total body water and body fat in young women in a course of menstrual cycle. Int Jnl Anthropology 2006; 21: 55–60.
13. Harrison GG, Buskirk ER, Carter JEL et al. Skinfold thicknessess and measurement technique. In: Lohman TG, Roche AF, Martorell R eds. Anthropometric standardization reference manual 1998; 55–70.
14. Heyward VH, Stolarczyk LM. Applied body composition assessment. Champaign (IL): Human Kinetics publishing company; 1996: 20.
15. Roche AF, Heymsfield SB, Lohman TG eds. Human Body Composition. Champaign (IL): Human Kinetics Publishing Company; 1996.
16. Akern STA / BIA Body Composition Analyzer. Operators Manual. Akern Srl, Florence, Italy 2000; 17.
17. Kyle UG, Gentom L, Slosman DO, Pichard C. Fat-free and fat mass percentiles in 5225 healthy subjects aged 15 to 98 years. Am J Clin Nutr 2001; 17: 534–41.
18. Kyle UG, Bosaeus I, De Lorenzo AD et al. Bioelectrical impedance analysis. Part I: review of principles and methods. Clinical Nutrition 2004; 23: 1226–43.
19. Gaddis ML, Gaddis GM. Introduction to Biostatistics. Annals of Emergency Medicine 1990; 19(1): 86–9; 19(3): 308–15; 19(5): 591–7.
20. Talluri T. Qualitative human body composition assessed with bioelectrical impedance. Collegium Antropologicum 1998; 22: 427–32.
21. Barbosa-Silva MCG, Barros AJD, Wang J, Heymsfield SB, Pierson RN Jr. Bioelectrical impedance analysis: population reference values for phase angle by age and sex Am J Clin Nutr 2005; 82: 49–52.
22. Buffa R, Marini E, Floris G. 2004. Bioelectrical Impedance Vector Analysis (BIVA) in the Sardinian population. European Anthropological Association. In: Biennial books of EAA 2004; 3: 99–109.
23. Bosy-Westphal A. Phase angle from bioelectrical impedance analysis: population reference values by age, sex, and body mass index. JPEN J Parenter Enteral Nutr 2005; 29: 148–56.
24. McArdle W, Katch F, Katch V. Exercise physiology: energy, nutrition and human performance. 4th ed. Baltimore: Williams & Wilkins; 1996: 541–75.