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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Comparative analysis of measuring the body fat percentage by anthropometric methods and bioimpedance

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SUMMARY

Introduction/Objective Body fat percentage (BFP) is the most reliable indicator of the nutritional status. For clinical practice, it is important but also insufficiently examined whether the determination of BFP should be relied exclusively on the latest methods or whether classical anthropometric methods are also reliable. The aim was to investigate the correlation between the results of BFP measuring using a contemporary method of bioimpedance and classic methods of skin fold thickness (SFT) and body mass index (BMI).

Method There were 279 patients of the Dietetic Counseling Center of the Institute for Public Health in Niš who were included in the research during 2015. BFP was determined using three classic anthropometric methods: SFT over the triceps, SFT over the scapula, and BMI. OMRON BF 302 apparatus was used for BFP measuring using the bioimpedance method.

Results Using single-factor analysis of variance we found a statistically significant difference between the mean values of the BFP obtained with bioimpedance and those obtained with anthropometric methods ($F = 24.19$, $p < 0.05$). *Post hoc* analysis revealed a statistically significant difference between the BFP determined with bioimpedance and SFT over the triceps and the scapula, while the anthropometric method based on BMI gave the results similar to those from bioimpedance.

Conclusion We show that the most reliable anthropometric method of determination of BFP is that based on BMI, as its results correlate best with those obtained with a contemporary method of bioimpedance.

Keywords: body fat percentage; BMI; bioimpedance

INTRODUCTION

Body fat percentage (BFP) as a part of the overall body weight gives the most reliable assessment of nutritional status [1]. There are several contemporary methods of determining BFP: bioimpedance, hydro densitometry, air-displacement plethysmography, dual-energy X-ray densitometry, computerized tomography, nuclear magnetic resonance, and near-infrared [2–10].

For this research, we used a bioimpedance method as non-invasive, relatively simple electrical conductivity method based on tissue properties to provide resistance to low-intensity electric current flow. Under the influence of impulses of a low-dose safe alternating current (800 μA), the cells and tissues provide resistance or an electrical bioimpedance that depends on the tissue structure and the frequency of the signal used. Therefore, the frequency response of the electrical impedance of biological tissues is greatly under the influence of their physiological and physicochemical status and varies from subject to subject. It varies from tissue to tissue in a particular subject, as well as with a change in the health status depending on the physiological and physicochemical changes, which occur in the tissue. Non-fatty tissue rich in electrolytes and water (73%) is a good electrical conductor, whereas fatty tissue poor in electrolytes and water (14%) shows great resistance and is a weak conductor [2, 3, 4]. The bioimpedance analysis could also be useful in the planning of physical activity for overweight/obese children and adolescents [11]. The coronavirus disease of 2019 (COVID-19) pandemic has showed that the timely identification and correction of undernutrition also have the potential to improve outcomes of the disease cost-effectively. Practical steps to improve nutritional status at a time when hospital services are particularly stretched are also important [12]. The clinical relevance of the anthropometric data on patients obtained by the bioimpedance is also confirmed [13].

Contemporary methods of BFP measurements are accurate but also expensive, and the research question is whether classic methods based on skin fold thickness (SFT) and on BMI should be abandoned in a clinical practice.

The aim of this investigation was to examine the correlation between the results of BFP measurements obtained with classic anthropometric methods of SFT and BMI and one contemporary method – bioimpedance. The working hypothesis of the research was that some of the classic methods of BFP measurement correlate strongly and positively with the

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contemporary method of bioimpedance and that it can be further recommended for clinical practice.

METHODS

Sample

There were 279 patients of the Dietetic Counseling Center of the Institute for Public Health in Niš who were included in the research during 2015. The inclusion criteria for the study were the following: age between 18 and 59 years, BMI greater than 25, and the absence of chronic illnesses. This information was obtained from the patients' medical records.

Body fat percentage measurements

Body height and body weight and SFT over the triceps and the scapula were measured. The SFT was determined using a mechanical caliper (John Bull British Indicators Ltd). Also, BFP was determined in all the examinees using the OMRON BF 302 apparatus (OMRON Healthcare Co., Ltd., Kyoto, Japan) based on bioimpedance. Trained personnel performed all measurements three times and the mean values were calculated. The examinees were advised not to drink diuretics seven days before the measurement, not to drink alcoholic drinks two days prior to measurements, not to exercise intensively 24 hours prior to measurements, and not to drink any fluids four hours before the measurements.

The BFP determination using classic anthropometric measurements was calculated in three ways: 1) based on SFT over the triceps; 2) based on SFT over the scapula, and 3) based on the BMI. For these three methods, we used the following formulas:

1) $D1 = 1.0923 - 0.0202 \times SFT_t$; $F1 = (4.201 / D1 - 3.813) \times 100$ [1]

SFT_t – skin fold thickness over triceps;
D1 – specific body density based on Sty;
F1 – BFP based on D1;

2) $D2 = 1.089 - 0.0179 \times SFT_s$; $F2 = (4.201 / D2 - 3.813) \times 100$ [1]

SFT_s – skin fold thickness over the scapula;
D2 – specific body density based on SFTs;
F2 – BFP based on D2;

3) BMI is calculated using the following formula:

$BMI = weight (kg) / [height (m)]^2$
$F3 = 1.2 \times BMI + 0.23 \times years - 10.8 \times sex - 5.4$
(male = 1; female = 0) [14]
F3 – BFP based on BMI;

The measurement of BFP using the bioimpedance method was carried out with the OMRON BF 302 instrument, which performs measurements on the upper body. Before measurements were taken, data on a patient's body height, body weight, age, and sex were entered. The device is held with extended arms at an angle of 90º in relation to the body. The elbows are held straight, and the body is not moved during the measurement. The ring finger and little finger are laid around the lower part of the electrode and the middle finger around the dents on the holder between the electrodes. With the thumb and forefinger, a patient firmly tightens the upper part of the electrode.

After taking the right position, a patient tightens the electrodes firmly with hands. The measurement takes about 20 seconds. The BFP value is seen on the display of the device. To each patient it was precisely explained how to stand and to hold the device properly. All the patients were informed about the nature of the study and were asked to sign a written consent form. They had the opportunity to end the monitoring at any time. The authors also followed the latest version of the Declaration of Helsinki given by the World Medical Association and the study was done in accordance with standards of the institutional committee on ethics (Ethics Committee of the Public Health Institute, Niš; No. 12-3785/5).

Statistical methods

The primary data were analyzed by descriptive statistical methods, methods for testing the difference of mean values, and the method for determining the correlation between variables. From the descriptive statistical methods, the measure of central tendency (mean) and measurement of variability (standard deviation) were used. To test the difference in numerical data, Student's t-test and ANOVA repeated measurements were used with the Bonferroni *post hoc* analysis. For the correlation of the tested values, the Spearman's coefficient of correlation was used. Statistical hypotheses were tested at a significance level of 0.05.

RESULTS

There were 279 participants included in the research [159 (57%) females and 120 (43%) males]. The average age was 36.09 ± 14.26 years.

Men had higher body mass and body height than women. Concerning anthropometric indexes, women had higher BFP than men (Table 1).

Using one-way ANOVA for repeated measurements, we determined a statistically significant difference between the mean values of fat percentage obtained by bioimpedance and three anthropometric methods [F (24.19), $p < 0.05$]. By a further *post hoc* analysis, we found that there was a statistically significant difference between the percentage of fat determined by bioimpedance and indexes F1 and F2. There was no statistically significant difference between the values of F1 and F2. Also, there were no statistically significant differences between the percentage of fat determined by bioimpedance and index F3 (Table 2).

All the correlation coefficients between the BFP obtained by bioimpedance and other measurements by indexes F1, F2, and F3 were positive and significant. The strongest correlation was between index F3 and bioimpedance in both sexes (Table 3).

Table 1. Anthropometric indicators of examinees related to the sex (mean value ± standard deviation)

Characteristics	Whole sample (n = 279)	Men (n = 120)	Women (n = 159)	t	p
Body mass (kg)	88. 65 ± 15.96	96.37 ± 13.80	82.89 ± 15.03	- 8.311	< 0.05
Body height (m)	1.68 ± 0.1	1.75 ± 0.09	1.63 ± 0.07	- 12.48	< 0.05
BMI	31.35 ± 4.54	31.68 ±3.76	31.1 ± 5.06	-1.54	0.297
Bio (%)	31.78 ± 7.57	28.84 ±7.01	33.99 ± 7.23	11.05	< 0.05
F1 (%)	39.06 ± 26.59	32.23 ± 20.76	44.22 ± 29.28	4.09	< 0.05
F2 (%)	41.44 ± 23.91	40.22 ± 23.59	42.36 ± 24.19	0.52	0.433
F3 (%)	32.88 ± 9.04	29.5 ± 6.26	35.58 ± 8.42	12.88	< 0.05

BMI – body mass index; Bio – percentage of fat determined by bioimpedance; F1 – percentage of fat in the body determined based on SFT over the triceps; F2 – percentage of fat in the body determined based on SFT over the scapula; F3 – percentage of fat in the body based on body mass index

Table 2. Difference between mean values of the body fat percentage based on bioimpedance (Bio) and those based on the anthropometric indicators

Method	Method	p
Bio	F1	< 0.05
	F2	< 0.05
	F3	0.09
F1	F2	0.34
	F3	< 0.05
F2	F3	< 0.05

One-way ANOVA for repeated measurements, *post hoc* Bonferroni method;
F1 – percentage of fat in the body determined based on SFT over the triceps;
F2 – percentage of fat in the body determined based on SFT over the scapula;
F3 – percentage of fat in the body based on body mass index

Table 3. Correlation (Spearman–Brown correlation coefficient) between body fat percentage based on bioimpedance and anthropometric indicators in relation to sex

Method	Whole sample (n = 279)	Men (n = 120)	Women (n = 159)
F1	0.658*	0.654*	0.659*
F2	0.642*	0.638*	0.646*
F3	0.701*	0.682*	0.726*

F1 – percentage of fat in the body determined based on SFT over the triceps;
F2 – percentage of fat in the body determined based on SFT over the scapula;
F3 – percentage of fat in the body based on body mass index;
*a value of p < 0.05 was considered statistically significant

The correlation analysis in relation to age showed that all BFP determined by bioimpedance and anthropometrics were significantly and positively related. At the age of 18–25 years, the strongest correlation is between the BFP determined by bioimpedance and the F1 index (BFP based on SFT over triceps). In all other age groups, the strongest correlation was between BFP based on bioimpedance and BMI (Table 4).

Correlation analysis stratified in relation to BMI showed a significant positive correlation between the BFP based on bioimpedance and three used indexes with the exception of the F2 index for BMI ≥ 35 (our measurement of skin thickness may not have been precise enough due to the large amount of fat tissue above the scapula). In the group of the examinees whose BMI is in the range 30–34.9, the strongest correlation was between BFP based on bioimpedance and the F1 index. However, this connection is weak. In the other two groups, the correlation of BFP based on bioimpedance and the F3 index is the strongest, and this is a strong association (Table 5).

Table 4. Correlation (Spearman–Brown correlation coefficient) between body fat percentage based on bioimpedance and anthropometric indicators in relation to age

Method	Age			
	18–25	26–35	36–45	≥ 46
F1	0.676*	0.710*	0.419*	0.667*
F2	0.615*	0.631*	0.433*	0.676*
F3	0.429*	0.851*	0.618*	0.731*

F1 – percentage of fat in the body determined based on SFT over the triceps; F2 – percentage of fat in the body determined based on SFT over the scapula; F3 – percentage of fat in the body based on body mass index;
*a value of p < 0.05 was considered statistically significant

Table 5. Correlation (Spearman–Brown correlation coefficient) between body fat percentage based on bioimpedance and anthropometric indicators in relation to body mass index

Method	BMI		
	25–29.9	30–34.9	≥ 35
F1	0.558*	0.391*	0.541*
F2	0.465*	0.272*	0.222
F3	0.610*	0.285*	0.676*

F1 – percent of fats in the body determined based on SFT over the triceps;
F2 – percentage of fat in the body determined based on SFT over the scapula;
F3 – percentage of fat in the body based on body mass index; BMI – body mass index;
*a value of p < 0.05 was considered statistically significant

DISCUSSION

In our research, we show that the most appropriate anthropometric method for BFP measurement is based on BMI, because it gives the closest results and it correlates best with the modern bioimpedance method.

Today, in clinical practice and in scientific research, BMI and different indexes for determining BFP are used, but the World Health Organization officially recommends only BMI as the anthropometric method of BFP determination [15]. Some countries have developed their own standards N1, N2 [16, 17, 18]. However, there are shortcomings of this method that have been proven in various studies [19, 20, 21]. That is why there is a need to use some other anthropometric method of BFP determination, together with BMI. However, there is a problem in how to choose the appropriate index. The practice that has been proven as successful is that each country should determine the combination of indexes for BFP. It seems that body fat distribution may be country- or nation-specific [17, 22]. In our research, we compared different anthropometric indicators and, to our knowledge, the results presented here are the first of their kind in Serbia.

From all indexes which follow the percentage of fat in the body the highest mean value in the sample was determined using index based on SFT_s, whereas the lowest percentage of fat was determined using the bioimpedance method, and this method showed the lowest standard deviation. It indicates that this index was the most stable throughout the entire research. However, the method based on BMI has also a small standard deviation, which is also in favor of its stability throughout the measurements. These results are similar to the findings of previous studies that showed that the calculation of BFP based on SFT was error-prone and with considerable variation across age, sex, and ethnicity [23]. High standard deviations with indexes based on SFT_s and b on SFT_t speak about the insufficient precision of the method.

Earlier research demonstrated a good correlation between BMI and BFP calculated or measured by different methods [24]. Nevertheless, some inconsistencies were found, most likely due to the fact that the calculation of BMI does not include age and sex. However, BFP based on BMI in our study takes into account sex and age [25, 26].

Due to this, it is highly expected that the strong correlation between the results of BFP measurer using bioimpedance and index based on BMI was found in the whole sample but also according to sex and in different age and BMI categories.

That is why the method of determining BFP using BMI can be recommended in both epidemiological studies and clinical practice. This is important since there is limited access to the advanced methods of BFP measuring in Serbia

CONCLUSION

The only anthropometric method of BFP measurement suitable for clinical practice and research is the one based on BMI because its results strongly correlate with the results based on the bioimpedance method. Anthropometric methods based on SFT over the triceps and the scapula significantly vary in the results from the method of bioimpedance and they are of low precision.

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Conflict of interest: None declared.

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Упоредна анализа одређивања процента масти у телу антропометријским методама и биоимпеданцом

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САЖЕТАК

Увод/Циљ Проценат масти у телу је најпоузданији показатељ степена ухрањености. За клиничку праксу важно је али и недовољно испитано да ли се у одређивању процента телесне масти треба ослањати искључиво на најсавременије методе или су поуздане и класичне антропометријске методе.

Циљ истраживања био је да се испита корелација између резултата мерења процента масти у телу савременом методом биоелектричне импеданце и класичним антропометријским методама дебљине кожног набора (ДКН) и индекса телесне масе (ИТМ).

Методе У истраживање је укључено 279 пацијената Саветовалишта за дијететику у Институту за јавно здравље Ниш током 2015. године. Проценат телесне масти класичним антропометријским мерењима одређен је на три начина: на основу ДКН над трицепсом; на основу ДКН над скапулом и на основу ИТМ. Такође свим испитаницима је апаратом ОМРОН БФ 302 на бази биоимпеданце одређен проценат телесне масти.

Резултати Једнофакторском анализом варијансе поновљених мерења утврђена је статистички значајна разлика између средњих вредности процента масти добијених биоимпеданцом и помоћу три антропометријске методе (F (24,19), $p < 0,05$). Даљом *post hoc* анализом утврдили смо да постоји статистички значајна разлика између процента масти одређеног биоимпеданцом и на основу ДКН над трицепсом и над скапулом, док антропометријска метода на основу ИТМ даје резултате сличне резултатима биоимпеданце.

Закључак У нашем истраживању показали смо да је за одређивање процента масти најпрепоручљивија антропометријска метода она на основу ИТМ, јер најбоље корелира са савременом методом биоимпеданце.

Кључне речи: проценат масног ткива; индекс телесне масе; биоимпеданца