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# Comparison of body fat using various bioelectrical impedance analyzers in university students

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**Background:** At present, the portfolio of devices using the bioelectrical impedance (BIA) method is continuously expanding as a result of the wide use of this method in the field as measurements by this method are fast and staff training is simple and reasonably priced. Nonetheless, the problem is that despite using the same method, bioimpedance analyzers can differ in many parameters. They use different electric current frequencies, a different number of electrodes and the electric current may be conducted through different parts of the body. **Objective:** The main objective of the study is to compare and evaluate the differences of values of the analysis of the body fat of university students measured by BIA analyzers that differ in the applied electric current frequency, number of electrodes and flow of the electric current through the individual body parts. **Methods:** The research included 125 participants (70 male and 55 female). The measurements were taken by the following analyzers: Tanita 418 MA, InBody 720, InBody R20 and Omron BF 300. **Results:** The differences in the mean values of the body fat representation between the used analyzers in men ranged from 0.1 to 3.4% and from 0.0 to 2.4 kg, in women from 0.5 to 6.5% and from 0.4 to 3.8 kg in relation to the used analyzer. **Conclusions:** In men with regular physical activity, the values measured by InBody R20 were statistically and practically different. The analyzer measured higher values that other analyzers. In women, there were statistically and practically significant differences in the values measured by Omron BF 300. This analyzer measured lower values than other analyzers.

*Keywords:* adipose tissue, young adult, single frequency analyzer, multi frequency analyzer, Bland-Altman analysis

## Introduction

Nowadays, the evaluation of body composition is commonly used for the assessment of the medical condition of an individual, the level of nutrition and physical fitness (McArdle, Katch, & Katch, 2007). In medicine, it is used as a part of diagnostics in diabetics, nephrology, obesity science and osteology (Parikh et al., 2004; Pluijm et al., 2001; Pravn et al., 1999). In sports, it facilitates efficient management of the training process. On the basis of the body composition evaluation, we can to some extent determine the level of readiness of the athlete's organism for strain. By monitoring changes in the body composition, we can also evaluate the effect of physical exercise on the athlete's organism and asses its adequacy (Bauer, Pivarnik, Fornetti, Jallo, & Nassar, 2005; Green, Pivarnik, Carrier, & Womack, 2006; Quinney et al., 2008; Rahimi, 2006; Sanchez, Sanz, & Zabala, 2007) in medicine, it helps us assess the effect of the applied treatment (such as diet). Very often monitored parameter is therefore body fat (BF).

There are many methods applied to the evaluation of body composition that can be classified as reference and non-reference. According to Heyward and Wagner (2004) the reference methods ("gold standard") are underwater weighting, air-displacement plethysmography and dual-energy X-ray absorptiometry (DEXA). These methods are used for the evaluation of the validity of other (non-reference) methods. Since the reference methods are demanding for equipment as well as implementation of measurement, they are mainly used in medicine. In practice, non-reference methods are used most frequently: these are field methods (standardized anthropometry, methods based on bioelectrical impedance analysis) that allow examining larger sample groups in the field, are less demanding for instrumentation and also are affordable. There have already been many studies that compare the final values

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of the body composition parameters acquired by various methods. There have been comparisons of results measured by the DEXA method (and other laboratory methods), anthropometric methods as well as the bioelectrical impedance method (BIA). The studies state both the found differences in the final values of the measured parameters and the validity of the applied methods to laboratory methods (Beeson et al., 2010; Dolezal, Lau, Abrazado, Storer, & Cooper, 2013; Gába, Kapuš, Cuberek, & Botek, 2015; Gupta, Balasekaran, Victor, Hwa, & Shun, 2011; Leahy, O'Neill, Sohun, & Jakeman, 2012; Mojtahedi, Valentine, & Evans 2009; Rutherford, Diemer, & Scott 2011).

At present, however, the portfolio of devices using the BIA method is continuously expanding as a result of the wide use of this method in the field as measurements by this method are fast and staff training is simple and reasonably priced. Nonetheless, the problem is that despite using the same method, bioimpedance analyzers can differ in many parameters. They use different electric current frequencies, a different number of electrodes and the electric current may be conducted through different parts of the body. Another issue is the unavailability of the used equations in the analyzer software and the lack of information about the proband groups from which reference data were taken for the calculation of the final values. It is not possible to calculate any potential differences in the final values when more sophisticated instrumentation or an analyzer by a different producer is acquired. A similar problem may occur when the individual is measured in a different work station. The only way how to encompass such differences is to take such measurements in practice and check any potential differences. The knowledge of any potential differences is essential in case of repeated measurements with the aim to understand changes in body composition that could be caused by ontogenetic changes or external interventions.

The main objective of the study is to compare and evaluate the differences of values of the analysis of the body fat of university students measured by bioimpedance analyzers that differ in the applied electric current frequency, number of electrodes and flow of the electric current through the individual body parts.

## Methods

### Participants

The research group included 130 individuals in total (73 males and 57 females). Three male and two female were removed from the group after outliers. Thus, the final number of monitored individuals was 125 (70 males and 55 females). The basic characteristic of the study sample is presented in the Results part in Table 1. None of the participants had any medical issues; they did not take any medicine or food supplements. They participated in the research voluntarily and they were informed about the process of the research in advance. Also, they signed informed consent with the participation in the research. The research was approved by the Ethical Board of the University of Ostrava and it is in compliance with the Helsinki Declaration. The males were university students studying physical education and sports. Therefore, we can call them a specific population group and the acquired results may be applied to athletes of a whole range of sports disciplines that will show similar values of the monitored parameters (e.g. body fat representation which is a very frequently monitored parameter in sports). The females were university students of fields that did not focus on sports. Therefore, we can apply their results on the general population of women without any medical problems.

### Procedures

The participants of the measurements were informed of the conditions they had to observe prior to measurement in advance (no alcohol consumption for 24 hours prior to measurement, no vigorous exercise less than 12 hours prior to measurement, no food and beverages 3 hours prior to measurement, urination immediately before measurement; only women that did not have their menstrual period were measured).

Measurements took place in the morning (7.30 a.m.–9.00 a.m.) on the same day in the week. All principles of measurement defined in the operating instructions for the individual analyzers were met. The participants attended all measurements wearing underwear. The measurement was executed standing, always by the same team of researchers who have several years of experience with such measurements. The body fat of each participant was successively measured on all applied BIA analyzers in the following order: Tanita 418 MA ($SFBIA_4$), InBody 720 ($MFBIA_{4\text{-}720}$), InBody R20 ($MFBIA_{4\text{-}R20}$), Omron BF 300 ($SFBIA_2$). To exclude any potential influence of the final measured value due to delays between measurements (e.g. by consumption of food or liquids), the individual measurements were executed in immediate succession and the participants were under continuous supervision. The total body water (TBW), which is a primarily measured parameter when the BIA method is used, was also measured. TBW values are not stated for the $SFBIA_2$ analyzer because the output of this analyzer does not specify the value. The body height, which is an input parameter for measurements by the used analyzers, was measured using the A-226 anthropometer (Trystom, Olomouc, Czech Republic). The body weight as

an input parameter for the Omron BF 300 analyzer, which is not a scale, was taken by the Tanita BC 587 digital scale (Tanita Corporation, Tokyo, Japan).

The used analyzers for the body composition diagnostics and their basic characteristics:

- Tanita 418 MA (Tanita Corporation, Tokyo, Japan) is a tetrapolar single-frequency BIA analyzer that uses the electric current frequency of 50 kHz for measurement. Eight point touch electrodes are used for measurement. The analyzer is also a digital scale.
- InBody 720 (Biospace, Seoul, Korea) is a tetrapolar multi-frequency BIA analyzer that uses the gradual electric current frequency of 1, 5, 50, 250, 500 and 1000 kHz for measurement. Eight point touch electrodes are used for measurement. The analyzer is also a digital scale.
- InBody R20 (Biospace, Seoul, Korea) is a tetrapolar multi-frequency BIA analyzer that uses the electric current frequency of 20 and 100 kHz for measurement. Eight point touch electrodes are used for measurement. The analyzer is also a digital scale.
- Omron BF 300 (Omron Corporation, Tokyo, Japan) is a bipolar single-frequency BIA analyzer (hand-hand) that uses the electric current frequency of 50 kHz for measurement.

**Statistical processing**

The results were statistically processed using the IBM SPSS Statistics (Version 21; IBM, Armonk, NY, USA). Remote observations were identified by box plots and the normality of distribution was verified by the Shapiro-Wilk test. With regard to the normal distribution of values, we used the paired samples t-test to verify the statistical significance of the differences of the results between the individual devices. The statistical significance level was determined to be $\alpha = .05$ for all tests used.

In values where statistically significant differences were found, we used the effect size to assess practical significance (Cohen, 1988). Recommendations for Cohen's *d*: 0.2 = minor change, 0.5 = medium change, 0.8 = major change. The value of Cohen's $d \geq 0.5$ was considered to be a practically significant difference.

To express the level of correlation between the results of measurement by the individual analyzers for the body fat, we used Pearson correlation coefficient (Westgard, 2008). To evaluate the homogeneity of the results between two analyzers, we also used the Bland-Altman's analysis (Bland & Altman, 2010).

## Results

The basic characteristics of the monitored group and the BF value measured by the individual analyzers are presented in Table 1 and 2.

The differences in the values of the measured BF and TBW representation by the used analyzers and the results of their statistical analyses are presented in Table 3 and 4.

Table 1
*Characteristics of the monitored group*

| | Males ($n$ = 70) | | Females ($n$ = 55) | |
|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* |
| Age (years) | 20.2 | 1.1 | 19.8 | 1.2 |
| Height (cm) | 180.8 | 5.9 | 166.6 | 6.0 |
| Weight (kg) | | | | |
| $SFBIA_4$ | 75.1 | 7.4 | 59.2 | 5.9 |
| $MFBIA_{4\text{-}720}$ | 75.1 | 7.7 | 59.4 | 5.8 |
| $MFBIA_{4\text{-}R20}$ | 75.2 | 7.4 | 59.3 | 5.9 |
| BMI ($kg/m^2$) | 23.0 | 1.6 | 21.4 | 1.8 |

*Note.* BMI = body mass index, $SFBIA_4$ = Tanita BC 418 MA, $MFBIA_{4\text{-}720}$ = InBody 720, $MFBIA_{4\text{-}R20}$ = InBody R20

Table 2
*Values of the body fat and total body water*

| | Males ($n$ = 70) | | Females ($n$ = 55) | |
|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* |
| BF (%) | | | | |
| $SFBIA_4$ | 10.6 | 4.0 | 24.2 | 4.1 |
| $MFBIA_{4\text{-}720}$ | 10.6 | 4.0 | 23.6 | 5.1 |
| $MFBIA_{4\text{-}R20}$ | 13.2 | 4.0 | 25.2 | 5.0 |
| $SFBIA_2$ | 9.6 | 3.3 | 19.0 | 3.9 |
| BF (kg) | | | | |
| $SFBIA_4$ | 8.0 | 3.3 | 14.3 | 3.4 |
| $MFBIA_{4\text{-}720}$ | 8.0 | 3.4 | 14.0 | 3.5 |
| $MFBIA_{4\text{-}R20}$ | 9.9 | 3.4 | 15.0 | 3.3 |
| $SFBIA_2$ | 7.2 | 3.0 | 11.3 | 3.0 |
| TBW (%) | | | | |
| $SFBIA_4$ | 65.4 | 2.9 | 55.2 | 2.9 |
| $MFBIA_{4\text{-}720}$ | 65.6 | 3.0 | 55.7 | 3.9 |
| $MFBIA_{4\text{-}R20}$ | 64.0 | 2.9 | 55.1 | 3.7 |
| TBW (kg) | | | | |
| $SFBIA_4$ | 49.1 | 4.5 | 32.7 | 2.6 |
| $MFBIA_{4\text{-}720}$ | 49.3 | 4.8 | 33.1 | 3.7 |
| $MFBIA_{4\text{-}R20}$ | 48.1 | 4.7 | 32.7 | 3.7 |

*Note.* BF = body fat, TBW = total body water, $SFBIA_4$ = Tanita BC 418 MA, $MFBIA_{4\text{-}720}$ = InBody 720, $MFBIA_{4\text{-}R20}$ = InBody R20, $SFBIA_2$ = Omron BF 300.

Table 3
*Differences in measured values – males (n = 70)*

| | Diff | *r* | *d* | 95% LoA |
|---|---|---|---|---|
| $SFBIA_4$ vs. $MFBIA_{4\text{-}720}$ | | | | |
| BF (%) | 0.0 | .68 | – | (–6.3, 6.3) |
| BF (kg) | 0.0 | .75 | – | (–4.8, 4.8) |
| TBW (%) | –0.2 | .65 | – | (–5.0, 4.6) |
| TBW (kg) | –0.2 | .93 | – | (–3.6, 3.2) |
| $SFBIA_4$ vs. $MFBIA_{4\text{-}R20}$ | | | | |
| BF (%) | –2.6*** | .67 | 0.6 | (–9.1, 3.9) |
| BF (kg) | –1.9*** | .75 | 0.5 | (–6.7, 2.9) |
| TBW (%) | 1.4*** | .63 | 0.5 | (–3.5, 6.3) |
| TBW (kg) | 1.0*** | .93 | 0.2 | (–2.4, 4.4) |
| $MFBIA_{4\text{-}720}$ vs. $MFBIA_{4\text{-}R20}$ | | | | |
| BF (%) | –2.6*** | .81 | 0.6 | (–7.4, 2.2) |
| BF (kg) | –1.9*** | .84 | 0.5 | (–5.7, 1.9) |
| TBW (%) | 1.6*** | .79 | 0.5 | (–2.1, 5.3) |
| TBW (kg) | 1.2*** | .95 | 0.3 | (–4.1, 1.7) |
| $SFBIA_4$ vs. $SFBIA_2$ | | | | |
| BF (%) | 1.0** | .77 | 0.2 | (–4.0, 6.0) |
| BF (kg) | 0.8** | .82 | 0.1 | (–3.1, 4.7) |
| $MFBIA_{4\text{-}720}$ vs. $SFBIA_2$ | | | | |
| BF (%) | 1.0** | .66 | 0.2 | (–5.0, 7.0) |
| BF (kg) | 0.8** | .72 | 0.1 | (–3.9, 5.5) |
| $MFBIA_{4\text{-}R20}$ vs. $SFBIA_2$ | | | | |
| BF (%) | 3.6*** | .64 | 0.9 | (–2.6, 9.8) |
| BF (kg) | 2.7*** | .72 | 0.7 | (–2.2, 7.4) |

*Note.* Diff = difference, *r* = Pearson correlation coefficient, *d* = effect size, 95% LoA = 95% limits of agreement, $SFBIA_4$ = Tanita BC 418 MA, $MFBIA_{4\text{-}720}$ = InBody 720, $MFBIA_{4\text{-}R20}$ = InBody R20, $SFBIA_2$ = Omron BF 300. $^{**}p < .001$, $^{***}p < .0001$.

There was no significant difference in the measured results only between the analyzers $SFBIA_4$ and $MFBIA_{4\text{-}720}$. In other cases, the final significance values ranged from $p < .001$ to $p < .0001$. As for results with significant differences, medium practical significance was found between the results of $SFBIA_4$ and $MFBIA_{4\text{-}R20}$ (BF %, kg and TBW %), $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$ (BF %, kg and TBW %) and $MFBIA_{4\text{-}R20}$ and $SFBIA_2$ (BF %, kg) ($d = 0.5$–$0.7$) and high practical significance only between $MFBIA_{4\text{-}R20}$ and $SFBIA_2$ in the values expressed in percentage ($d = 0.9$). Practical significance between the analyzers $SFBIA_4$ and $MFBIA_{4\text{-}R20}$ (TBW kg), $MFBIA_{4\text{-}720}$ vs. $MFBIA_{4\text{-}R20}$ (TBW kg), $SFBIA_4$ – $SFBIA_2$ and $MFBIA_{4\text{-}720}$ and $SFBIA_2$ was not shown in spite of significant differences ($d = 0.1$–$0.3$). The closeness of results between the individual analyzers expressed in kilograms can be considered to be high, up to very high (Westgard, 2008). The values of Pearson's correlation coefficient *r* explain 51–90% of variability. In values expressed in percentage, there is a high closeness of results only between the values of the analyzers $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$ and $SFBIA_4$ and $SFBIA_2$. The *r* values explain 59–65% of variability. The closeness of results between other analyzers is considerable (Westgard, 2008). The *r* values explain 41–46% of variability.

Similarly to the men, there was no significant difference in the measured values between $SFBIA_4$ and $MFBIA_{4\text{-}720}$; moreover, the female group also did not show any significant difference in the values between $SFBIA_4$ and $MFBIA_{4\text{-}R20}$ (except BF %). In other cases, the significance ranged from $p < .05$ to $p = .0001$. In spite of the significant difference in the results of $SFBIA_4$ and $MFBIA_{4\text{-}R20}$ (BF %), $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$ (BF %, kg and TBW %, kg), practical significance was not shown ($d = 0.1$–$0.3$). The practical significance in other cases was always high ($d \geq 0.8$). The values of the Pearson's correlation coefficient *r* show higher correlations between the results measured by the used analyzers than in men. The closeness of

Table 4
*Differences in measured values - females (n = 55)*

| | Diff | *r* | *d* | 95% LoA |
|---|---|---|---|---|
| $SFBIA_4$ vs. $MFBIA_{4\text{-}720}$ | | | | |
| BF (%) | 0.6 | .75 | – | (–6.4, 7.6) |
| BF (kg) | 0.3 | .82 | – | (–4.6, 4.0) |
| TBW (%) | –0.5 | .71 | – | (–6.0, 5.0) |
| TBW (kg) | –0.4 | .94 | – | (–3.6, 2.8) |
| $SFBIA_4$ vs. $MFBIA_{4\text{-}R20}$ | | | | |
| BF (%) | –1.0* | .71 | 0.2 | (–6.0, 8.0) |
| BF (kg) | –0.7 | .81 | – | (–4.9, 3.5) |
| TBW (%) | 0.1 | .72 | – | (–4.8, 5.0) |
| TBW (kg) | 0.0 | .95 | – | (–3.0, 3.0) |
| $MFBIA_{4\text{-}720}$ vs. $MFBIA_{4\text{-}R20}$ | | | | |
| BF (%) | –1.6*** | .94 | 0.3 | (–5.1, 1.9) |
| BF (kg) | –1.0*** | .95 | 0.2 | (–3.1, 1.1) |
| TBW (%) | 0.6** | .90 | 0.2 | (–2.8, 4.0) |
| TBW (kg) | 0.4** | .97 | 0.1 | (–1.4, 2.2) |
| $SFBIA_4$ vs. $SFBIA_2$ | | | | |
| BF (%) | 5.2*** | .82 | 1.3 | (–9.9, –0.5) |
| BF (kg) | 3.0*** | .89 | 1.0 | (0.0, 6.0) |
| $MFBIA_{4\text{-}720}$ vs. $SFBIA_2$ | | | | |
| BF (%) | 4.6*** | .74 | 1.0 | (–2.2, 11.4) |
| BF (kg) | 2.7*** | .82 | 0.8 | (–1.3, 6.7) |
| $MFBIA_{4\text{-}R20}$ vs. $SFBIA_2$ | | | | |
| BF (%) | 6.2*** | .74 | 1.4 | (–0.1, 12.5) |
| BF (kg) | 3.7*** | .84 | 1.1 | (0.2, 7.2) |

*Note.* Diff = difference, *r* = Pearson correlation coefficient, *d* = effect size, 95% LoA = 95% limits of agreement, $SFBIA_4$ = Tanita BC 418 MA, $MFBIA_{4\text{-}720}$ = InBody 720, $MFBIA_{4\text{-}R20}$ = InBody R20, $SFBIA_2$ = Omron BF 300. *$p < .05$, **$p < .001$, ***$p < .0001$.

results is high, up to very high (Westgard, 2008). The *r* values between analyzers $SFBIA_4$ and $MFBIA_{4\text{-}720}$ (TBW kg), $SFBIA_4$ and $MFBIA_{4\text{-}R20}$ (TBW kg), and $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$ (BF, TBW % and kg) explain 81–94% of variability. In other cases, the values range from 50 to 79%.

The results of the Bland-Altman's analysis of BF representation (a primarily monitored parameter in this study) are illustrated in the form of Bland-Altman's plots (Figures 1 and 2). The plots present the differences found in BF values expressed in percentage, measured by two different analyzers. The plots show that for the male group, the smallest differences in the mean are between analyzers $MFBIA_{4\text{-}720}$ and $SFBIA_4$ where the mean is almost zero (mean = 0.6). In women, there were differences between $MFBIA_{4\text{-}720}$ and $SFBIA_4$ and $MFBIA_{4\text{-}R20}$ and $SFBIA_4$ (mean = –3.5 and 3.6). However, according to the 95% interval of agreement, there are large differences in the individual persons among the analyzers, which are manifested by the wide interval of agreement. To assess the size of the values measured by the individual analyzers, we can use the assessment of mean displacement (the Mean axis) in the plots. The displacement of the mean axis downwards means that the results measured by the second analyzer are higher than the results measured by the first analyzers. The displacement of the mean axis upwards means that the results measured by the first analyzer are higher than the results measured by the second analyzer. As an example of the mean displacement downwards, in the male group we provide a comparison between $MFBA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$ (mean = –24.4) where $MFBIA_{4\text{-}R20}$ measures considerably higher values. As an example of the mean displacement upwards, in the male group we provide a comparison between $MFBIA_{4\text{-}R20}$ and $SFBIA_2$ (mean = 32.6) where $MFBIA_{4\text{-}R20}$ also measured considerably higher values. The relative differences in the measured values in the individual participants are mostly concentrated around the mean relative difference in the values of

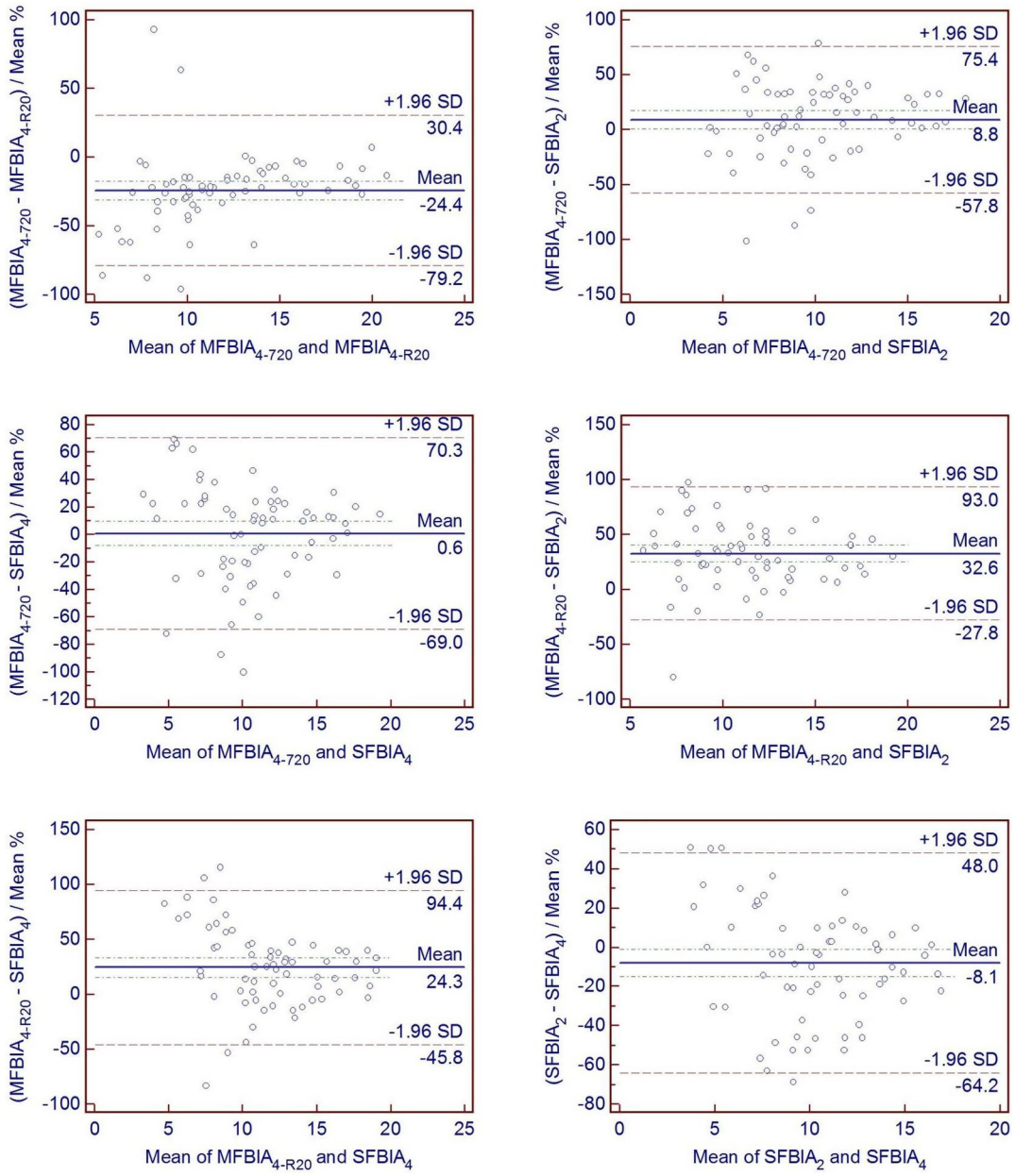


*Figure 1.* Bland-Altman plots with 95% limits of agreement and correlation analysis of the differences between the body fat values measured by the used analyzers in percentage – males

the two analyzers $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$ which is also reflected in the values of the Pearson's correlation coefficient *r* (Tables 3 and 4). It is thus obvious that these two analyzers provide the most predictable results. The analyzers have one manufacturer and therefore they should have the same software for the calculation of BF.

## Discussion

The study used BIA analyzers that use different frequencies for the measurement, with electric current going through different body parts. The objective of the study was not to evaluate their validity against the reference method as many studies dealing with this issue have already been published. For the InBody analyzers, the correlation with the DEXA reference method was determined to be at the level of .94–.96; the study included healthy men and women by the age of 18 (Karelis, Chamberland, Aubertin-Leheudre, & Duval, 2013). Even though they used a different analyzer than we did in this study, we can assume that the InBody analyzers we used will have similar correlations as they are made by the same manufacturer and use the same frequencies, number of electrodes as well as the method of conducting current through the human

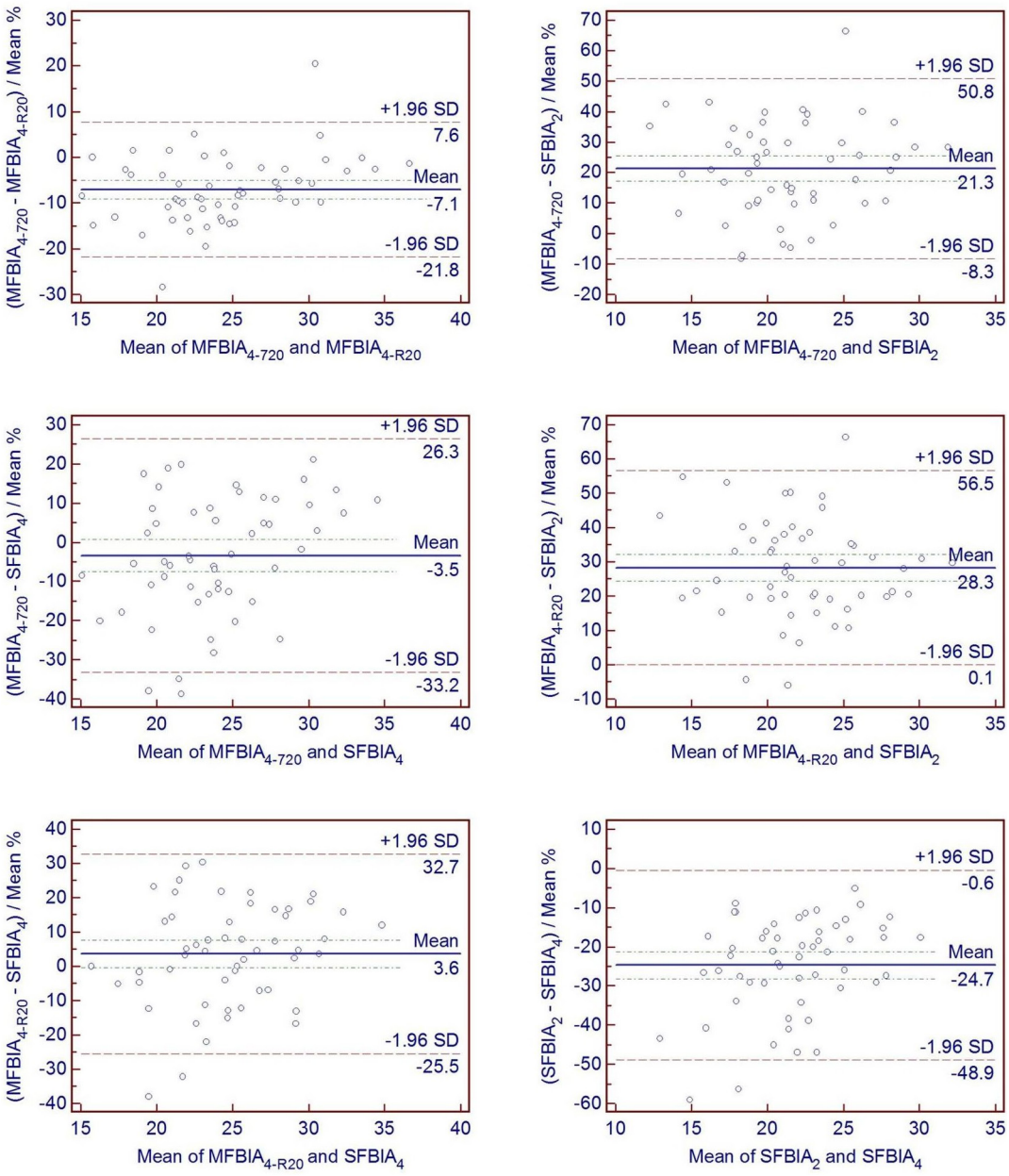


*Figure 2.* Bland-Altman plots with 95% limits of agreement and correlation analysis of the differences between the body fat values measured by the used analyzers in percentage – females

body for the measurement. As for the single-frequency analyzer $SFBIA_4$, the value of correlation to the DEXA method found in physical education students was .82–.84 in relation to the used measuring mode (Kutáč, Gajda, Přidalová, & Šmajstrla, 2008). As for single frequency bipolar hand-to-hand analyzers, the values of correlation with the DEXA method for the verification of validity in sporting young men and women ranged from .82 to .88 in relation to the used analyzers (Esco, Olson, Williford, Lizana, & Russell, 2011; Loenneke et al., 2013; Wang et al., 2013). Even though InBody seems to be the most accurate analyzer, other analyzers can also be considered sufficiently accurate as the values of correlation in all the aforementioned studies exceeded .8 which is a high closeness of results (Westgard, 2008). Analyzers with such closeness of results to the reference method may be considered to be sufficiently accurate for the needs of the process of physical education and diagnostics of athletes.

In the males, the lowest differences between the mean values of BF representation were found between the analyzers $SFBIA_4$ and $MFBIA_{4\text{-}720.}$ The overall analysis of the differences in the mean values measured by the individual BIA analyzers did not show any dependence that would be related to the used BIA analyzer. The difference in the values measured by the analyzer

of the same manufacturer, $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$ was greater than the difference between the single and multi-frequency analyzers $MFBIA_{4\text{-}720}$ and $SFBIA_4$ or $MFBIA_{4\text{-}720}$ and $SFBIA_2$. On the other hand, the difference between the analyzers $MFBIA_{4\text{-}R20}$ and $SFBIA_2$ was the greatest of all comparisons in the male.

The diagnostic practice also needs to respond to the question of the impact of the differences in the results on the interpretation of the measured values. The monitored men were students of physical education. The mean values of the BF representation percentage measured by the BIA method in physical education students that are presented in some professional studies do not exceed 13% (Kutáč, 2012; Kutáč, Gajda, & Přidalová, 2009; Kutáč, Přidalová, & Riegerová, 2008). Therefore, the detailed analysis of the values measured by the individual analyzers also focused on how many participants would correspond with the mean values of physical education students. The limit value was 13% of body fat. For the $SFBIA_4$ analyzer it was found that the body fat representation of 18 participants (25.71%) did not correspond with the values of physical education students (exceeded 13%); the number of 20 (28.57%) for $MFBIA_{4\text{-}720}$, 31 (44.28%) for $MFBIA_{4\text{-}R20}$ and 13 (18.57%) for $SFBIA_2$. The results show that there would be different evaluation of several participants in case of interpretation of the acquired results. There would be a significant difference especially when using $MFBIA_{4\text{-}R20.}$

In the females, similarly to males, the lowest differences in the mean values were found between the analyzers $SFBIA_4$ and $MFBIA_{4\text{-}720}$. The greatest differences were found between the single frequency BIA hand-to-hand analyzer ($SFBIA_2$) and the other analyzers. The $SFBIA_2$ analyzer measures the lowest values. The found differences were even higher than in the comparison of the measured values by the BIA and DEXA methods (Gupta et al., 2011; Mojtahedi et al., 2009; Kutáč et al., 2008; Trutschnigg et al., 2008). In these studies, the differences did not exceed 2.7% BF. To assess the impact of the found differences on the interpretation of results in the diagnostic practice, we will use the BF representation at the level of 25%, which is the value stated for young female (Görner, Boraczyński, & Štihec, 2009; Nazmi, Irfan, Osman, & Serdar, 2011; Rutherford, Diemer, & Scott, 2011). The value of 25% BF representation was exceeded in 25 female (45.45%) measured by $SFBIA_4$, in 16 women (29.09%) measured by $MFBIA_{4\text{-}720}$, in 27 (49.09%) measured by $MFBIA_{4\text{-}R20}$ and only in 5 (9.09%) measured by $SFBIA_2$. There is a noticeable difference that became apparent when the analyzer was changed. The greatest difference would occur with the use of $SFBIA_2$.

The differences in the mean values we found that were measured by the used BIA analyzers are lower than differences stated in other studies. The differences in studies that dealt with the comparison of whole-body analyzers with leg-to-leg analyzers reached the mean value of 7.4% BF, and the value of 6.2% BF when compared with hand-to-hand analyzers (Chin, Kiew, & Girandola, 2006; Trutschnigg et al., 2008).

TBW is the primarily measured parameter in the BIA method, BF values are calculated additionally. The TBW value predicates the status of organism hydration. Professional studies state that when hydration decreases by 2 to 3%, there is a substantial reduction of performance in physical activities (García-Jiménez, Lucas, & García-Pellicer, 2011; Hamouti, Del Coso, Estevez, & Mora-Rodriguez, 2010; Maughan & Shirreffs, 2010). A decrease of hydration by 3–5% causes digestive issues during training and muscle spasms (Beachle & Earle, 2008; Burke, 2007; Montain, 2008; Oppliger & Bartok, 2002). From this point of view, we can state that the differences we found in the mean values measured by the individual analyzers are negligible. Even though some differences were statistically significant and the value of Cohen's *d* showed the medium value of the effect of size, none of the differences exceeded the level of 2% TBW; the differences ranged from 0 to 1.6% TBW. As for BF, the differences found were within the difference intentions. However, a more detailed analysis of the differences in the individual participants showed that the difference in the range of 2–3% TBW was found in 13 (18.6%) males between $SFBIA_4$ and $MFBIA_{4\text{-}720}$, in 16 (22.3%) males between $SFBIA_4$ and $MFBIA_{4\text{-}R20}$, and in 11 (15.7%) males between $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$. As for females, there were 11 (20%) participants between $SFBIA_4$ and $MFBIA_{4\text{-}720}$, 15 (27.3%) between $SFBIA_4$ and $MFBIA_{4\text{-}R20}$, and 6 (10.1%) between $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$. The difference in the range of 3 to 5% TBW was found in 10 (14.3%) males between $SFBIA_4$ and $MFBIA_{4\text{-}720}$, 19 (27.1%) males between $SFBIA_4$ and $MFBIA_{4\text{-}R20}$, and 16 (22.9%) males between $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$. In females, the difference was found in 13 (23.6%) participants between $SFBIA_4$ and $MFBIA_{4\text{-}720}$, 11 (20%) between $SFBIA_4$ and $MFBIA_{4\text{-}R20}$, and 3 (5.5%) between $MFBIA_{4\text{-}720}$ and $MFBIA_{4\text{-}R20}$. As the detailed analysis implies, the evaluation of the final values of several participants could be misinterpreted if the analyzers were changed.

**Study limitations**

We are aware of the fact that the results we obtained might be influenced by the selected groups. The monitored males are individuals with regular physical activity which they perform in their field of study. These

individuals are also active athletes at the performance level. Therefore, their results may only apply to the sporting population.

The validity of the results is also limited by the used BIA analyzers. Since there is a wide range of BIA analyzers on the market, the submitted study could be considered a base for including other BIA analyzers, or other population groups in the research.

## Conclusions

Even though the differences between the mean values measured by the used analyzers were low in majority of the cases and ranged at the level of the errors of measurement, a detailed analysis showed substantially higher differences in several participants. Replacing an analyzer with a different one could lead to misinterpretation of the measured values in diagnostics. The differences found during repeated measurements would not need to be a result of an external intervention or the ontogenetic development of the individual; they could be caused by different measuring of the analyzers. The results also showed significant (statistically and practically) differences between analyzers by the same manufacturer, but a different series. It is thus obvious that a high correlation of measured values does not guarantee conformity of results and therefore, it is not recommended to even use different types of analyzers by one producer in practice.

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