

## Comparison of the results of bioelectric impedance analysis (BIA) and the anthropometry (Drinkwater-Ross & Parizkova) method in young elite athletes

BALÁZS FÜGEDI<sup>1</sup>, ZSOLT SZAKÁLY<sup>2</sup>, LÁSZLÓ SUSZTER<sup>3</sup>

<sup>1,3</sup>Department of Sport Science, Catholic University of Károly Eszterházy, Eger, HUNGARY

<sup>2</sup>Department of Sport Science, University of Széchenyi, Győr, HUNGARY

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### Abstract

**BACKGROUND:** The literature provides relatively few and incomplete studies on comparisons of body composition measurement procedures, especially when related to sport experience, gender and age. The purpose of this study was to compare and contrast the applicability of the bioelectric impedance (BIA) and the four-component anthropometry (Drinkwater-Ross) methods among young athletes. **METHODS:** 142 school-aged competitive athletes ( $n_{\text{male}}=71$ ;  $n_{\text{female}}=71$ ,  $M_{\text{age}}=11.72\pm2.33$ ) from a suburb in Hungary participated in the study. Data collection included standard Drinkwater-Ross anthropometric fractionation (bone mass, muscle and fat mass, and residual mass, estimated by equations) and bioelectrical impedance analysis with measured muscle mass (SMM\_Inbody) and body fat percentage (PBF%Inbody) methods. In order to better understand the higher standard correlations of the methods, Parizkova percentage of body fat (Parizkova BF%) was also included in the analysis. Data analysis was performed by gender and age range. **RESULTS:** According to the data, it seems that the muscle mass estimated by BIA (SMM Inbody) is higher than the Drinkwater-Ross estimation (eMM) both in males and females and in each age-group. Also, muscle mass is overestimated, meanwhile body fat% (PBF% Inbody) is underestimated by BIA compared to Parizkova BF%. However, our results show significant correlations ( $0.6\leq r\leq 0.9$ ,  $p<.001$ ) between estimated fat mass and muscle mass in all cases (eMM, eFM); similarly, the estimated body fat percentages in all cases were strongly correlated (Parizkova BF% and PBF% Inbody). **CONCLUSIONS:** Correlational analyses proved that estimation of body fat mass, muscle mass, and percentage of body fat by BIA measurement are closely associated with both Drinkwater-Ross anthropometric fractionation and Parizkova. Our findings suggest that the (BIA) predictive performance is equally appropriate as other reference techniques (e.g. Drinkwater-Ross, Parizkova) in the case of young athletes. Consequently, both the device (bioelectrical impedance device) and the ease of use of the results make for a truly user-friendly and scientifically supported procedure.

**Key Words:** estimated body composition, measured body composition, age-range and elite athletes

### Introduction

Participating in regular physical activity (PA) during school years influences healthy active adult life (Kraut, Melamed, Gofer & Froom, 2003; Malina, Bouchard & Bar-Or, 2004; Szakály et al, 2016; Kolokoltsev et al, 2022). Positive and long lasting effects of both regular physical activity and sports on objective and subjective health have been supported by scientific evidence. Body composition measurement is an indispensable type of investigation to evaluate aspects of health in both athletes and non-athletes (Suszter et al, 2021). A sports prodigy is considered to have outstanding health, psychological, physiological, anthropometric, and socialization abilities that make it likely for the athlete to achieve a high level of sports performance. (Révész, Bognár, Gécsi & Benczenleitner, 2005). Therefore, anthropometric measurements are important; body composition measurements can monitor the effects of the training program on the body composition, determine optimal competitive body weight, and help athletes control weight and alter body composition safely (Prior et al. 2001). One of the most widely used instrumental techniques to assess body composition is the bioelectrical impedance analysis (BIA) method which is well-known in the case of epidemiological investigations (Kyle, Genton, Slosman & Pichard, 2001). However, there are only a few research reports available to verify the validity and applicability of this method for diverse subgroups (Deurenberg et al. 2001; Deurenberg & Deurenberg-Yap, 2002; Moreno, Gandoy, Gonzalez, Herranz, De La Camara & de Otero, 2001; Moreno, Gandoy & Gonzalez, 2001).

Besides the body fat mass and lean body mass, the BIA estimates the total body water. As another advantage of this method, it also provides comprehensive information on specific parts of the body. Skinfold (SKF) thickness measurement has been amongst the recommended methods for determining the body fat percentage (BF%) for some time now (Durnin & Womersley, 1974; Parizkova, 1961). It is considered the simplest and most inexpensive technique available in the epidemiological settings (Schaefer, Georgi, Weuhl &

Scheerer, 1998). SKF has been the most commonly used two-component model to estimate the subcutaneous fat mass, and with this data, the lean body mass (LBM) can be calculated as well (Davies & Cole, 1995).

Nowadays, the Drinkwater-Ross four-component anthropometric method is very popular. This method is commonly used to determine body composition fractions in human biology and health care (Drinkwater & Ross, 1980). It separated the body components indirectly, based on the characteristics of the different dimensions of the body size. According to its theoretical model, body weight can be divided into four different components: bone mass, fat mass, muscle mass, and viscera/residual mass. The popularity of the procedure lays in its reliability and validity, which was demonstrated in numerous studies (Davies & Cole, 1995; Fuller, Jebb, Laskey, Coward, & Elia, 1992; Heymsfield et al. 1990).

#### *Body compositions in athletes*

Body composition of athletes has been widely studied, however, only limited data is available on BIA accuracy in the athletic population, and the accuracy of the BIA to determine body components for an athletic population is currently ambiguous (Company & Ball, 2010; Pápai et al. 2022). Furthermore, there seems to be insufficient research that focus on comparing and contrasting the BIA with standard anthropometric measurements in various young athletes' populations.

Two studies need to be highlighted because their aim was to develop a DXA-dependent BIA prediction equation for athletes. Fornetti et al. (1999) investigated the reliability and validity of BIA in 132 female athletes participating in a variety of Division in university sports. Compared to DXA, their BIA equation predicted FFM with a 1.1-kg standard of error. This study reported that BIA was a reliable and valid estimate for body composition and single trial measurement is sufficient in obtaining reliable results (Fornetti, Pivarnik, Foley & Fiechtner, 1999). Correspondingly, Yannakoulia et al. (Yannakoulia, Keramopoulous, Tsakalakos & Antonia-Leda, 2000) developed a DXA-derived BIA equation for young female dancers. The authors concluded that the new BIA equation accurately assesses body composition in this group, but they also stated that further validation studies are needed for cross-validation.

Previously, a BIA vs. DEXA analysis study among athletes (Company & Ball, 2010) stated that the BIA significantly overestimated the body fat percentage. Comparison of the endurance and strength dominance groups did not result in significant differences when estimating with bioelectrical impedance, indicating that bioelectrical impedance has the same error rate for both groups. This prediction equation used bioelectrical impedance analysis measurements and anthropometric measurements, including trunk measurements, to account for trunk size, which tends to be a common source of error rate in bioelectrical impedance analysis equations (Company & Ball, 2010).

In a method comparison study (Lintsi, Kaarma & Kull, 2004), bioelectrical impedance analysis (BIA), skinfold (SKF) thickness and body mass index (BMI) based equations, and dual-energy X-ray absorptiometry (DEXA) as a criterion method were compared and contrasted for the assessment of body fat percentage (BF%) in 17–18-year-old Estonian novice athletes. The BIA body fat monitor estimated that BF% was lower than the criterion method of DEXA. Three anthropometric equations estimated a BF% higher than that of DEXA. Earlier, Durnin, and Womersley (1974) reported that SKF equation BF% was higher than that of the DEXA. Knechtle et al. found that total body fat estimated by BIA was significantly higher when compared with anthropometry (Knechtle, Wirth, Knechtle, Rosemann, Rüst & Bescós, 2011).

Deurenberg et al. (2001) and Gallagher et al. (Gallagher, Heymsfield, Heo, Jebb, Murgatroyd & Sakamoto, 2000) produced overestimations in their BMI-based equations. From the anthropometric equations, only the Deurenberg et al. (2001) SKF equation was slightly underestimated. DEXA-assessed BF% had the highest correlation with SKF equations, less so with BIA, and the lowest with BMI equation-assessed BF%. They concluded that the BIA body fat monitor and the anthropometric Deurenberg et al. (2001) SKF equation yielded results close to the DEXA BF%. However, data are not yet validated for athletes.

Shim et al. (Shim, Cross, Norman & Hauer, 2014) aimed to determine whether various convenient and affordable body composition techniques correlated well with more costly, “gold standard” instruments to measure body composition in female college athletes. Thirty-two Division I track and field and basketball player female athletes participated in their study. Within one hour, each subject underwent body composition assessments via air displacement plethysmography (ADP), skinfold (SF) measurements, and bioelectrical impedance analysis (BIA). There were no significant differences between basketball and track athletes; thus, data was normalized. No significant difference in calculated percent body fat was noted between ADP and SF ( $p = .002$ ), but a significant difference was found between ADP and BIA ( $p = .478$ ). Per Pearson correlations, moderate correlations existed between body fat percentages obtained by ADP and SF ( $r = .689$ ) as well as between body fat percentages estimated by ADP and BIA ( $r = .447$ ). Results indicated that the SF technique had the highest correlation when compared to the BOD POD. Skinfold measurements obtained with the Harpenden Skinfold Calipers may be used as a quick, affordable, and reliable technique for measuring body fat percentages in female college athletes when performed by an experienced skinfold assessor.

Sixty-four Caucasian and thirty six African-American Division IAA football players took part in Brock et al. (Brock, Nieman, Utter, Harris & Rossi, 2001) study. The purpose of the study was to validate leg-to-leg bioelectrical impedance analysis (BIA) methodology for estimating body composition football athletes of different races. Fat free mass (FFM) and percentage of body fat were also estimated from underwater weighing

(UW), seven-site skinfold measurement (SK), and BIA. A significant correlation in estimating FFM was found between underwater weighing and BIA ( $r = 0.94, p < 0.001$ ; SEE 3.7 kg), and between underwater weighing and skinfold thickness measurement ( $r = 0.97, p < 0.001$ ; SEE 2.6 kg). The mean difference in estimation of FFM between underwater weighing and BIA was  $-0.46 \pm 3.8$  kg. They did not find a significant correlation ( $r = 0.10, p = .166$ ) between the estimation of FFM from underwater weighing and the difference in estimation of FFM between underwater weighing and BIA. This indicates that there was no systematic underestimation or overestimation of FFM in either Caucasian or African-American athletes. They concluded that the leg-to-leg BIA system provided a quick and accurate method to determine the body composition of football players compared to the conventional underwater weighing.

Ostojic (2006) compared two different field used methods – skinfolds (SKF) versus bioelectric impedance analysis (BIA) – to estimate body fat in top-level athletes. 219 male professional athletes participated in their study. Skinfold thickness was measured by caliper, and total body resistance was measured with a bioelectrical impedance analyzer. There was a non-significant difference in body fat percentage (%BF) between the average %BFSKF and %BF BIA ( $p > 0.05$ ). The average time of assessment per subject was significantly longer during skinfold measurement ( $p < 0.01$ ) than during the BIA assessment. The estimates of body fat in SKF and BIA were similar with significant correlation ( $r = 0.96$ ) between methods while the BIA method was found less time-consuming. In conclusion, the simplest, fastest, and most inexpensive method of BIA seems to be very useful for the dietitians' routine to assess body fat in physically active individuals and athletes.

Hetzler et al. (Hetzler, Kimura, Haines, Labotz & Smith, 2006) wanted to know whether bioelectrical impedance (BIA) and skinfold (SF) analysis can be used interchangeably to establish minimal wrestling weights (MWWs). They thought that using both methods in a particular program could result in the misclassification of some athletes. 208 wrestlers (151 males, 57 females), aged 13 to 18 years participated in their study to compare the MWW calculated from SF measurements with those derived from 5 BIA equations and to determine if the two methods could be used interchangeably for high school wrestlers. Repeated measurements were obtained using the BIA and the SF analysis to determine MWWs. The MWWs were based on a minimum body fat of 7.0% for males and 14.0% for females. When comparing the BIA and the SF analyses, the prediction error ranged from 1.51 to 2.34 kg for males and 0.27 to 9.16 kg for females. It was concluded that to protect the health of the athletes and to maintain competitive equity, a single method should be used to determine MWWs. The BIA and the SF analysis cannot be used interchangeably to determine MWWs.

Michailidis et al. (Michailidis, Methenitis & Michailidis, 2013) compared the arm-to-leg BIA system and skinfolds to estimate the percentage of body fat (BF%) in senior professional soccer players. 28 players participated in the study. Body composition was determined from the 7 skinfold measures using the Brozek et al., prediction equation. The BIA measurements were determined using the BC-418 Segmental Body Composition Analyzer. Pearson correlation coefficient between methods was  $r=0.56$  ( $p<0.01$ ). Fat percentage values differed between techniques ( $p<0.001$ ). The BIA overestimated BF% by 27.81%. The study demonstrated that the arm-to-leg BIA system does not accurately assess BF% when compared to skinfolds in soccer players. Hence, the aim of this study is to compare and find a correlation between the predictive results (fat and muscle mass and body fat percentages) measured by the InBody720 instrument (BIA) and the Drinkwater-Ross method estimated data during the assessment of young elite athletes.

## Material & methods

### Participants

Participants ( $N=142$ ;  $n_{\text{male}}=71$ ;  $n_{\text{female}}=71$ ;  $M_{\text{age}}=11.72 \pm 2.33$ ) were randomly selected from a primary school with a sports-focused curriculum in a suburb in Hungary. The selection criterion was that students were active members of elite sport teams in their respective sports (basketball, handball, ice skate, track and field, tennis, soccer, gymnastics). An elite sport group was defined as a high level of daily training (minimum 5 times a week) involving a regular high intensity training (Maximal Heart Rate% between 75 and 100), and also as an involvement with national top level competitions in their respective age-range. Groups were formed by gender (male and female) and age range (pre-puberty<12 and puberty>12).

### Data collection and analysis

Anthropometry data was collected by using the recommendations of the National Biology Program (Weiner & Lourie, 1969). The anthropometry characteristics were measured according to Drinkwater-Ross (Drinkwater & Ross, 1980) and Parízkova (Parízkova, 1961) suggestions. Instruments were produced by DKSH Switzerland Ltd (described in „Anthropologie, Handbuch der vergleichenden Biologie des Menschen, Band 1” Knußmann, R. (Hrsg.), Fischer, Stuttgart 1988/1992). SKFs were measured using the Lange Skinfold Caliper (Beta Technology, CA, USA). The prediction equations for the body composition were estimated with the Drinkwater-Ross (1980) four components anthropometry method, Parízkova (1961) and the BIA method (Kyle et al. 2004). For a higher quality of analysis and better comparability the analysis, Parízkova body fat% (Parízkova BF%) was also calculated and tested for correlation.

BIA method was carried out by an InBody720 body composition analyzer for medical research (Biospace Corp., Seoul, Korea) using tetra polar 8-point tactile electrodes under standard conditions described in BIA guidelines (Kyle et al. 2004). InBody720 body composition analyzer is considered valid and reliable.

*Data analysis*

SPSS for Windows 19.0 (IBM SPSS Inc., NY, USA, 2010) was used for statistical analysis. The difference between the groups (gender, age) were analyzed by t-test. Correlation between gender and age ranges was computed by using Pearson's correlation in  $p > 5\%$  level.

*Ethical considerations*

The study was conducted according to the Declaration of Helsinki (1964) and Declaration of Tokyo (1975), as revised in 1983. Prior to the research, parental consent was obtained from each participant's parents and the Ethic Committee of the University also approved this study.

**Results**

Descriptive statistics and grouping differences by gender and biological developmental ranges are presented in Table 1. There were no significant differences between the pre-puberty and the puberty age-groups in males and females. Males' biological development is more one-sided than females' during puberty and also at the end of puberty.

Males are taller and stronger as gender differences are marked in these periods. It is worth highlighting that muscle mass estimated by the BIA (SMM Inbody) is higher than Drinkwater-Ross estimation (eMM) both in males and females and in each age-group. It seems that muscle mass are overestimated, meanwhile body fat% (PBF% Inbody) are underestimated by the BIA compared to Parizkova BF%.

**Table 1.** Descriptive data of male and female athletes

| Variable      | Male (N=71)   |       | Male pre-puberty (N=40)   |      | Male puberty (N=31)   |       | p  |
|---------------|---------------|-------|---------------------------|------|-----------------------|-------|----|
|               | Mean          | SD    | Mean                      | SD   | Mean                  | SD    |    |
| BH            | 158,67        | 17,19 | 146,34                    | 9,48 | 174,35                | 10,75 | NS |
| BW            | 49,61         | 17,39 | 39,60                     | 8,35 | 62,34                 | 17,64 | NS |
| Parizkova BF% | 19,49         | 6,09  | 20,01                     | 6,39 | 18,82                 | 5,70  | NS |
| eMM           | 38,16         | 3,44  | 37,42                     | 3,96 | 39,10                 | 2,38  | NS |
| eFM           | 15,43         | 4,89  | 16,54                     | 5,32 | 14,03                 | 3,94  | NS |
| PBF% Inbody   | 13,77         | 7,64  | 15,28                     | 7,96 | 11,84                 | 6,86  | NS |
| SMM Inbody    | 46,84         | 4,58  | 45,15                     | 4,22 | 49,00                 | 4,14  | NS |
| Variable      | Female (N=71) |       | Female pre-puberty (N=38) |      | Female puberty (N=33) |       | p  |
|               | Mean          | SD    | Mean                      | SD   | Mean                  | SD    |    |
| BH            | 151,32        | 14,10 | 141,01                    | 8,26 | 163,23                | 9,17  | NS |
| BW            | 43,78         | 14,34 | 35,24                     | 8,89 | 53,67                 | 13,08 | NS |
| Parizkova BF% | 21,15         | 6,69  | 20,18                     | 6,71 | 22,28                 | 6,60  | NS |
| eMM           | 37,16         | 2,67  | 36,97                     | 3,02 | 37,38                 | 2,22  | NS |
| eFM           | 17,78         | 4,82  | 17,79                     | 5,18 | 17,77                 | 4,46  | NS |
| PBF% Inbody   | 17,91         | 7,66  | 17,80                     | 8,41 | 18,04                 | 6,82  | NS |
| SMM Inbody    | 43,81         | 3,92  | 42,98                     | 4,25 | 44,77                 | 3,30  | NS |

**Abbreviations:** BH: body height, BW: body weight, Parizkova BF%: body fat% by Parizkova, eMM: estimated muscle mass by Drinkwater-Ross, eFM: estimated fat mass by Drinkwater-Ross, PBF% Inbody: body fat% by Inbody, SMM Inbody: skeletal muscle mass by Inbody; NS: the difference is not significant

The correlation coefficient among the measured values were highly significant. In all cases, the coefficient was  $r > 0.6$  at level  $p < .001$ . The findings are demonstrated in separate tables for all males and females and also in the different biological development-groups (Tables from 2. and 3.).

**Table 2.** Correlation levels in males

| Variable      | All Groups Correlations Males (n=71) |      |               |             |             |             |             |
|---------------|--------------------------------------|------|---------------|-------------|-------------|-------------|-------------|
|               | BH                                   | BW   | Parizkova BF% | eMM         | eFM         | PBF% Inbody | SMM Inbody  |
| BH            | 1,00                                 | 0,86 | 0,04          | 0,22        | -0,15       | -0,14       | 0,40        |
| BW            | 0,86                                 | 1,00 | 0,35          | 0,03        | 0,12        | 0,18        | 0,08        |
| Parizkova BF% | 0,04                                 | 0,35 | 1,00          | -0,71       | <b>0,94</b> | <b>0,85</b> | -0,76       |
| eMM           | 0,22                                 | 0,03 | -0,71         | 1,00        | -0,83       | -0,69       | <b>0,70</b> |
| eFM           | -0,15                                | 0,12 | <b>0,94</b>   | -0,83       | 1,00        | <b>0,84</b> | -0,82       |
| PBF% Inbody   | -0,14                                | 0,18 | <b>0,85</b>   | -0,69       | <b>0,84</b> | 1,00        | -0,95       |
| SMM Inbody    | 0,40                                 | 0,08 | -0,76         | <b>0,70</b> | -0,82       | -0,95       | 1,00        |
| Variable      | Pre-puberty males (n=40)             |      |               |             |             |             |             |
|               | BH                                   | BW   | Parizkova BF% | eMM         | eFM         | PBF% Inbody | SMM Inbody  |
| BH            | 1,00                                 | 0,77 | 0,26          | -0,14       | 0,20        | 0,13        | 0,03        |

|                |       |       |             |             |             |             |             |
|----------------|-------|-------|-------------|-------------|-------------|-------------|-------------|
| BW             | 0,77  | 1,00  | 0,71        | -0,46       | 0,63        | 0,62        | -0,47       |
| Parízkova BF%  | 0,26  | 0,71  | 1,00        | -0,74       | <b>0,96</b> | <b>0,82</b> | -0,77       |
| eMM            | -0,14 | -0,46 | -0,74       | 1,00        | -0,81       | -0,66       | <b>0,63</b> |
| eFM            | 0,20  | 0,63  | <b>0,96</b> | -0,81       | 1,00        | <b>0,81</b> | -0,77       |
| PBF% Inbody    | 0,13  | 0,62  | <b>0,82</b> | -0,66       | <b>0,81</b> | 1,00        | -0,97       |
| SMM Inbody     | 0,03  | -0,47 | -0,77       | <b>0,63</b> | -0,77       | -0,97       | 1,00        |
| Puberty (n=31) |       |       |             |             |             |             |             |
| BH             | 1,00  | 0,81  | 0,15        | 0,43        | -0,09       | -0,00       | 0,21        |
| BW             | 0,81  | 1,00  | 0,54        | 0,07        | 0,29        | 0,40        | -0,18       |
| Parízkova BF%  | 0,15  | 0,54  | 1,00        | -0,69       | <b>0,93</b> | <b>0,91</b> | -0,84       |
| eMM            | 0,43  | 0,07  | -0,69       | 1,00        | -0,84       | -0,73       | <b>0,84</b> |
| eFM            | -0,09 | 0,29  | <b>0,93</b> | -0,84       | 1,00        | <b>0,90</b> | -0,91       |
| PBF% Inbody    | -0,00 | 0,40  | <b>0,91</b> | -0,73       | <b>0,90</b> | 1,00        | -0,96       |
| SMM Inbody     | 0,21  | -0,18 | -0,84       | <b>0,84</b> | -0,91       | -0,96       | 1,00        |

**Abbreviations:** BH: body height, BW: body weight, Parízkova BF%: body fat% by Parízkova, eMM: estimated muscle mass by Drinkwater-Ross, eFM: estimated fat mass by Drinkwater-Ross, PBF% Inbody: body fat% by Inbody, SMM Inbody: skeletal muscle mass by Inbody

Estimations of body fat mass (Drinkwater-Ross) were in high correlation ( $r > 0.8$  and  $0.9$ ) in each body fat percentage prediction model (Parízkova and Inbody) regardless of gender and age group. A less obvious correlation can be seen in muscle mass estimation between Inbody and Drinkwater-Ross method (SMM Inbody – eMM).

**Table 3.** Correlation levels in females

| Variable                   | Females all (n=71) |       |               |             |             |             |             |
|----------------------------|--------------------|-------|---------------|-------------|-------------|-------------|-------------|
|                            | BH                 | BW    | Parízkova BF% | eMM         | eFM         | PBF% Inbody | SMM Inbody  |
| BH                         | 1,00               | 0,86  | 0,44          | -0,14       | 0,28        | 0,19        | 0,08        |
| BW                         | 0,86               | 1,00  | 0,72          | -0,34       | 0,55        | 0,54        | -0,28       |
| Parízkova BF%              | 0,44               | 0,72  | 1,00          | -0,77       | <b>0,94</b> | <b>0,84</b> | -0,72       |
| eMM                        | -0,14              | -0,34 | -0,77         | 1,00        | -0,89       | -0,67       | <b>0,68</b> |
| eFM                        | 0,28               | 0,55  | <b>0,94</b>   | -0,89       | 1,00        | <b>0,81</b> | -0,76       |
| PBF% Inbody                | 0,19               | 0,54  | <b>0,84</b>   | -0,67       | <b>0,81</b> | 1,00        | -0,94       |
| SMM Inbody                 | 0,08               | -0,28 | -0,72         | <b>0,68</b> | -0,76       | -0,94       | 1,00        |
| Pre-puberty females (n=38) |                    |       |               |             |             |             |             |
| BH                         | 1,00               | 0,76  | 0,40          | -0,26       | 0,35        | 0,20        | -0,05       |
| BW                         | 0,76               | 1,00  | 0,75          | -0,50       | 0,67        | 0,64        | -0,51       |
| Parízkova BF%              | 0,40               | 0,75  | 1,00          | -0,84       | <b>0,95</b> | <b>0,82</b> | -0,77       |
| eMM                        | -0,26              | -0,50 | -0,84         | 1,00        | -0,92       | -0,68       | <b>0,70</b> |
| eFM                        | 0,35               | 0,67  | <b>0,95</b>   | -0,92       | 1,00        | <b>0,79</b> | -0,77       |
| PBF% Inbody                | 0,20               | 0,64  | <b>0,82</b>   | -0,68       | <b>0,79</b> | 1,00        | -0,97       |
| SMM Inbody                 | -0,05              | -0,51 | -0,77         | <b>0,70</b> | -0,77       | -0,97       | 1,00        |
| Puberty females (n=33)     |                    |       |               |             |             |             |             |
| BH                         | 1,00               | 0,77  | 0,65          | -0,45       | 0,60        | 0,43        | -0,29       |
| BW                         | 0,77               | 1,00  | 0,90          | -0,60       | 0,82        | 0,81        | -0,70       |
| Parízkova BF%              | 0,65               | 0,90  | 1,00          | -0,76       | <b>0,96</b> | 0,90        | -0,83       |
| eMM                        | -0,45              | -0,60 | -0,76         | 1,00        | -0,85       | -0,67       | <b>0,64</b> |
| eFM                        | 0,60               | 0,82  | <b>0,96</b>   | -0,85       | 1,00        | <b>0,86</b> | -0,81       |
| PBF% Inbody                | 0,43               | 0,81  | <b>0,90</b>   | -0,67       | <b>0,86</b> | 1,00        | -0,97       |
| SMM Inbody                 | -0,29              | -0,70 | -0,83         | <b>0,64</b> | -0,81       | -0,97       | 1,00        |

**Abbreviations:** BH: body height, BW: body weight, Parízkova BF%: body fat% by Parízkova, eMM: estimated muscle mass by Drinkwater-Ross, eFM: estimated fat mass by Drinkwater-Ross, PBF% Inbody: body fat% by Inbody, SMM Inbody: skeletal muscle mass by Inbody

## Discussion

The primary purpose of the present study was to compare the fat and muscle mass and body fat percentages among young elite athletes measured by the InBody720 and the Drinkwater-Ross method. Bioelectrical impedance analysis (BIA) produces a strong correlation in body fat percentage with estimated body fat mass (Drinkwater-Ross), but it seems to overestimate skeletal muscle mass when compared to the muscle mass values which were estimated by Drinkwater-Ross method. However, the body fat percentage estimation by the BIA is also in high correlation with other reference technique estimations (Parízkova).

Lohman et al. (2003) found that the variability of bioelectrical impedance is higher than a well-stated and defined standardized estimation model based on skinfolds data. Researchers also concluded deficiencies of the BIA, but there is no contradictory evidence when body composition is compared by anthropometry and the BIA methods in young elite athletes (Heymsfield, Lohman, Wang & Going, 2005; Lohman, 1992). Nevertheless, Phillips et al. (Phillips, Bandini, Compton, Numova & Must, 2003) found positive correlations between the different body composition methods.

Based upon the findings of this study, we can conclude that the BIA's predictive performance in case of young elite athletes is not worse than any other reference techniques (e.g. Drinkwater-Ross, Parízkova). Our results prove that the BIA method is a well-defined and reliable method for body composition analysis. These findings are in line with the result of the previous study (Turnagöl, 2016) that stated that body composition in athletes is associated with athletic performance, and the assessment of body composition in athletes by valid and reliable methods is of great importance for planning and evaluating training programs and nutrient intake over time. Sports practitioners and coaches should be aware of the importance of monitoring players' body composition and physical fitness to assess the physiological responses to the training process and to optimize training prescription (Franca, C., Franca, A., Marues, A., Ihle, A., Lopes, H., Santos, F., & Gouveia, R.É., 2022). Our findings also support the results of Ihász (2013) findings who stated that a reference technique (Parízkova) and the BIA is correlated on a high level ( $r=0.93$ ) in BF%, and is between estimated abdominal circumference (ADC) and BIA visceral fat (VFA) ( $r=0.87$ ).

## Conclusions

We can conclude that the anthropometry and the BIA methods are suitable for one another well. However, from the aspect of human biology, the professional content of the two methods can differ (e.g. diseases, medical treatment, sport, elite athletes, training method, nutritional status, etc.). In spite of the limitation of using data by the BIA method, the advantage of its application with young elite athletes is the quick and reliable feedback. For the future and for a more applicable method, the correction of regression equations can be considerable in both cases (BIA and anthropometry) where the level of physical activity, sport, and age range are considered, and the relative mass is predicted more precisely. The body composition depends on the participants' eating habits, lifestyle, and the level of involvement in physical activities. Therefore, these examinations must be regularly conducted and - when necessary - corrected (Martarelli, Martarelli & Pompei, 2008). However, monitoring athletes' body composition and physical fitness during the season and competition period are crucial to assessing the training process' physiological responses, which may be done using easy-field tests (Franca, C., Franca, A., Marues, A., Ihle, A., Lopes, H., Santos, F., & Gouveia, R.É., 2022), and we wish to conclude that the BIA fits this requirement. Last but not least, the advantage of the BIA method is easy application regarding both device and results.

## Conflict of interests

The authors declare that they have no conflict of interests regarding the publication of this paper.

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