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A Comparative and Sex-Specific Study of Bio-Electrical Impedance Analysis and Dual Energy X-ray Absorptiometry for Estimating Whole-Body and Segmental Body Composition in Healthy Young Adults

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Abstract: Bio-electrical impedance analysis (BIA) and dual-energy X-ray absorptiometry (DXA) are methods to estimate human body composition. This study aimed to compare sex-specific outcomes for estimating segmental and whole-body composition in 83 healthy participants (21.9 ± 1.5 years, 56% men) using Inbody S10 BIA and Norland Elite DXA devices. One-way repeated measures ANOVAs showed significantly lower whole-body fat% and whole-body fat mass values alongside higher whole-body lean mass values resulting from BIA when compared to DXA (both sexes: $p < 0.001$). In men, whole-body bone mineral content was significantly higher using BIA against DXA ($p < 0.001$). Regardless of sex, no significant BIA versus DXA difference was found in arm fat mass (men: $p = 0.180$, women: $p = 0.233$), whereas significantly lower leg fat mass values were found with BIA versus DXA (both sexes: $p < 0.001$). Additionally, significantly higher arm lean mass (both sexes: $p < 0.001$) and leg lean mass (only women: $p < 0.001$) were found in BIA versus DXA. Moderate to very strong positive associations ($p < 0.05$) between BIA and DXA outcome measures were found, except for arm fat mass (men: $p = 0.904$, women: $p = 0.130$) and leg fat mass (only men: $p = 0.845$). This study highlights (sex-dependent) differences in corresponding test outcomes between BIA and DXA both at the segmental and whole-body level.

Keywords: anthropometry; lean mass; fat mass; bone mineral content; body fat percentage; segmental analysis; Inbody S10; Norland Elite; arm; leg; upper and lower extremity

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1. Introduction

Human body composition is sex-specific in terms of its distribution (e.g., women tend to have a higher body fat percentage than men) and changes over time (e.g., women have shown to have stronger increases in body fat% than men during their university studies) [1]. Moreover, it is considered a crucial feature in various contexts, including athletic performance, overall physical fitness and health-related assessments [2,3]. In this regard, analyzing body composition at the segmental level has gained attention and has been linked to sport performance and injury risk [4,5]. As such, different non-invasive methods to indirectly assess body composition in humans have been developed through the years, with each technique having its own advantages and limitations.

Bioelectrical impedance analysis (BIA) estimates a person's body composition by spreading a low, constant and alternating electric current across the body [6]. More recent BIA devices, such as the InBody S10 (InBody, Seoul, Korea) [7], apply multiple electrodes and frequencies (i.e., 1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz and 1 MHz). They no longer use predetermined formulas or estimations concerning the measured individual's age and sex but only base their output on registered resistance of impedance outcomes. This allows practitioners to conduct segmental analyses with values for the trunk and each of the four limbs separately and, therefore, to monitor (the development of) bodily asymmetries [8]. BIA is a convenient, relatively low cost, field-based and reliable technique that also requires minimal participant action [9]. However, this technique is highly dependent on the amount of body water or the participant's hydration status and involves several prerequisites before actual testing (e.g., fasting, no exercise and no alcohol consumption prior to the measurement) [10].

Dual-energy X-ray absorptiometry (DXA) is a commonly used lab-based method for determining body composition founded on the principle of X-ray beam attenuation [11]. The extent to which the energy is attenuated when crossing the body depends on the thickness, density and chemical composition of the different tissues [11]. Originally, DXA has mainly been used for the assessment of areal bone mineral density, but nowadays it is increasingly considered the 'gold standard' for the (segmental) body composition assessment of bone mineral content, fat tissue and lean tissue [12]. The Norland Elite DXA (Swissray Medical AG, Hochdorf, Switzerland) [13] is a more recently developed DXA device, featured by a large scan window, a high weight capacity as well as a low and adaptive radiation dose. Although DXA has numerous advantages, including a relatively short measurement time and its applicability in humans of all ages [12], this method or technique also contains some limitations. As such, the DXA device uses minimal ionizing radiation and is not portable [14]. Furthermore, the purchase of a DXA device is relatively costly and it must be operated by a trained technician [14]. Therefore, DXA scans are more inconvenient to use among large samples in epidemiological field research.

Current literature suggests that BIA may be a usable alternative to DXA for the estimation of (segmental) body composition as this method is less expensive, faster and more applicable under field conditions compared to DXA [15]. In this respect, Esco et al. [16] investigated the (dis)agreement between BIA (i.e., InBody 720) and DXA (i.e., GE Lunar Prodigy) test outcomes for estimating body fat% and fat-free mass in addition to whole-body, arm and leg lean soft tissue in 45 female collegiate athletes. These authors demonstrated that BIA resulted in significantly lower whole-body fat% values and significantly higher whole-body fat-free mass values when compared to DXA, although there was an excellent agreement between both methods for whole-body and segmental lean soft tissue outcomes. Using Bland and Altman analyses, the study of Anderson and colleagues [17] reported good agreement between BIA (i.e., InBody 720) and DXA (i.e., GE Lunar DPX-iQ 2288) devices for whole-body fat mass and whole-body fat-free mass in men and for whole-body fat mass and segmental fat-free mass in women aged between 18 and 49 years. From these findings, it was concluded that BIA may serve as a suitable alternative of DXA for the (segmental) analysis of body composition. However, due to the mutual variation in results between different BIA and DXA devices, each device should be assessed separately [18,19].

To date, little research has been carried out on the (dis)agreement of segmental in addition to whole-body composition using BIA and DXA methods. Moreover, and to the best of our knowledge, there are currently no studies available comparing body composition outcome measures from the relatively new InBody S10 BIA device (InBody, Korea) [7] against the Norland Elite DXA scanner (Swissray Medical AG, Switzerland) [13] in young healthy adults. Therefore, the aim of this study was to compare the test outcomes from the InBody S10 BIA device and Norland Elite DXA scanner regarding body composition estimates of the whole-body (i.e., fat%, fat mass, lean mass and bone mineral content) as well as the arm and leg (i.e., fat mass and lean mass) in young healthy male and female adults.

2. Materials and Methods

2.1. Participants

Eighty-three healthy participants (47 men and 36 women, 21.8 ± 1.5 years) were recruited by means of convenience sampling to participate in the present observational cross-sectional study. Only healthy young adults, aged between 18 and 24 years and Caucasian were included in this study. All volunteers who were (possibly) pregnant and/or an individual with standard exclusion for BIA or DXA (e.g., when having an implanted defibrillator) were excluded from study participation. Participants with any disease or medical condition that may affect their (regional) body composition (e.g., amputation, diabetes, cancer) were also excluded. All eligible participants attended the Human Biometry Laboratory at the Faculty of Physical Education and Physical Therapy of the Vrije Universiteit Brussel (VUB, Belgium) at a single measurement moment in February or March. Apart from their personal test results, participants received no incentive for their participation in this comparative study. Participants were provided verbal and written information of the study purpose and design as well as the planned procedures and signed an informed consent upon agreement. Ethical approval was granted by the local medical ethical committee (B.U.N. 1423201837789).

2.2. Procedures

Both BIA and DXA measurements were performed on the same day, following a 2 h fast. Participants were instructed not to consume alcohol the night before or on the day of testing, to avoid exercise for at least 12 h prior to testing and to not use diuretics 7 days before testing. All participants were asked to empty their bladder before the start of the measurements as well as to remove all metal objects.

2.3. Anthropometric Measurements

The anthropometric variables of interest were measured by trained researchers, using standardized techniques and equipment as proposed by the International Society for the Advancement of Kinanthropometry (ISAK) [20]. All participants were measured while barefoot and wearing minimal clothing. Their body height was measured to the nearest 0.1 cm using a stadiometer (SECA 217, Hamburg, Germany), whereas a digital weighing scale (RADWAG WLT 60/120/X/L3, All scales Europe, Veen, The Netherlands) was used to measure their body weight to the nearest 0.002 kg. From these measurements, each participant's body mass index (BMI, kg/m^2) was calculated.

2.4. Bioelectrical Impedance Analysis

Whole-body and segmental body composition were estimated with the InBody S10 (InBody, Korea) [7]. This device is a multifrequency bioelectrical impedance analyzer providing six different frequencies (i.e., 1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz and 1 MHz) for impedance measurements of five different regions (i.e., trunk, right and left arm, right and left leg). Before the measurement, participants' hands and feet were wiped with an electrolyte tissue to enhance body conductivity. The 8-point touch-type electrodes were placed to their malleoli medialis and lateralis, their middle fingers and thumbs. The BIA measurement lasted approximately 2 min and was conducted on a non-conductive surface in a stationary supine position with both legs apart and the arms not touching the trunk. Whole-body fat% (to the nearest 0.001%), whole-body fat mass (to the nearest 0.01 kg), whole-body lean mass (to the nearest 0.01 kg), whole-body bone mineral content (to the nearest 0.01 kg) as well as arm fat mass (to the nearest 0.01 kg), leg fat mass (to the nearest 0.01 kg), arm lean mass (to the nearest 0.01 kg) and leg lean mass (to the nearest 0.01 kg) on the right-hand side of the body were registered as BIA-based outcome measures.

2.5. Dual-Energy X-ray Absorptiometry

The DXA-scan was conducted by trained researchers on a Norland Elite [13] (Swissray Medical AG, Switzerland). This DXA-device was calibrated according to the manufacturer's instructions each day prior to scanning. Participants were scanned in a supine position and were instructed to remain motionless during the scan. They all underwent a whole-body scan as well as a specific segmental research scan of their arm and leg on the right side of the body, taking about approximately 20 min in total. For these latter research scans (with a scan speed of 60.0 mm/s,, resolution of 6.0 mm × 6.0 mm and width of 30 cm as settings), the arm was bordered from the caput humeri to the distal phalanges of the hand and the leg was bordered from the caput femoris to the distal phalanges of the foot.

2.6. Statistical Analysis

Statistical analyses were conducted using SPSS 28.0.1 (IBM Corp., Armonk, NY, USA) with the alpha significance level set at 0.05. Descriptive characteristics for all outcome measures of interest are displayed as mean ± standard deviation according to the participant's sex. Data were tested for normality using the Shapiro–Wilk's tests and independent samples *t*-tests were conducted to examine possible sex differences. One-way repeated measures (RM) ANOVAs were performed for men and women separately to determine any significant differences in outcome measures according to body composition assessment method (i.e., within-subject factors): BIA versus DXA. The effect sizes of significant one-way RM ANOVA test results were reported using partial eta squared values (η_p^2). Sex-specific Pearson's r correlation coefficients between assessment methods were computed, with the absolute value of the correlation demarcated as follows [21]: negligible correlation (r < 30), weak correlation (r = 0.30–0.50), moderate correlation (r = 0.50–0.70), strong correlation (r = 0.70–0.90) and very strong correlation (r > 90). The Fisher r- to z-transformation was used to determine if these correlation coefficients between body composition assessment methods significantly differed between both sexes. Analyses were conducted for the whole-body, right arm and right leg test outcomes, respectively. The bias and 95% limits of agreement (95% LOA) were calculated for each outcome measure according to sex and graphically depicted using Bland–Altman plots [22], with the x-axis, representing the mean of both body composition assessment methods, and the y-axis, representing the difference between the two methods, compared. Finally, one sample *t*-tests were performed to determine whether or not the mean difference between both methods was significantly different from zero.

3. Results

Descriptive characteristics of the study sample are presented in Table 1. Age, height and weight were significantly different based on the participant's sex. In our sample, the included men were somewhat older, taller and heavier compared with their female counterparts. No statistically significant difference in BMI between male and female participants was found.

Table 1. Descriptive statistics of study sample characteristics (mean ± standard deviation) for male and female participants.

	Men (*n* = 47) Mean ± SD	**Women (*n* = 36) Mean ± SD**	**Independent Sample *t*-Test *p*-Value**
Age (years)	22.2 ± 1.2	21.2 ± 1.8	0.005 *
Height (cm)	180.8 ± 7.8	166.3 ± 7.1	<0.001 *
Weight (kg)	75.1 ± 11.4	62.2 ± 10.7	<0.001 *
BMI (kg/m^2)	22.9 ± 2.5	22.5 ± 3.7	0.554

SD: standard deviation, BMI: body mass index, *: significant sex differences ($p < 0.05$).

The results of the one-way RM ANOVAs for body fat%, fat mass, lean mass and bone mineral content at the whole-body and/or limb level (i.e., right arm and right leg) for male and female participants are displayed in Tables 2 and 3, respectively.

Table 2. Descriptive statistics (mean ± standard deviation) and one-way repeated measures ANOVA test results comparing BIA and DXA for body fat percentage, fat mass, lean mass and bone mineral content at the whole-body and/or segmental level on the right-hand side of the body for men (n = 47).

Male Participants	Mean ± SD	Mean Difference	p-Value	F-Value	Effect Size (n_p^2)
		Body fat (%)—Whole-body			
BIA DXA	14.0 ± 5.7 16.0 ± 6.0	2.0	<0.001 *	26.039	0.361
		Fat mass (kg)—Whole-body			
BIA DXA	10.8 ± 5.5 12.2 ± 5.6	1.4	<0.001 *	21.202	0.315
		Lean mass (kg)—Whole-body			
BIA DXA	60.6 ± 8.4 59.4 ± 8.9	1.2	<0.001 *	15.485	0.252
		Bone mineral content (kg)—Whole-body			
BIA DXA	3.7 ± 0.6 3.3 ± 0.6	0.4	<0.001 *	52.655	0.534
		Fat mass (kg)—Right arm			
BIA DXA	0.6 ± 0.5 0.7 ± 0.4	0.1	0.180	1.853	0.039
		Fat mass (kg)—Right leg			
BIA DXA	1.9 ± 0.9 3.0 ± 1.5	1.1	<0.001 *	17.270	0.273
		Lean mass (kg)—Right arm			
BIA DXA	3.6 ± 0.6 3.3 ± 0.6	0.3	<0.001 *	51.171	0.527
		Lean mass (kg)—Right leg			
BIA DXA	10.5 ± 1.5 10.5 ± 1.9	0.0	0.847	0.380	0.001

SD: standard deviation, η_p^2: partial eta squared values, BIA: bio-electrical impedance analysis, DXA: dual-energy X-ray absorptiometry, *: significant differences (p < 0.05) between BIA and DXA.

Table 3. Descriptive statistics (mean ± standard deviation) and one-way repeated measures ANOVA test results comparing BIA and DXA for body fat percentage, fat mass, lean mass and bone mineral content at the whole-body and/or segmental level on the right-hand side of the body for women (n = 36).

Female Participants	Mean ± SD	Mean Difference	p-Value	F-Value	Effect Size (n_p^2)
		Body fat (%)—Whole-body			
BIA DXA	25.5 ± 7.8 29.2 ± 6.6	3.7	<0.001 *	43.808	0.556
		Fat mass (kg)—Whole-body			
BIA DXA	16.4 ± 7.7 18.6 ± 6.9	2.2	<0.001 *	38.616	0.525
		Lean mass (kg)—Whole-body			
BIA DXA	43.5 ± 5.5 41.0 ± 5.5	2.5	<0.001 *	42.316	0.547
		Bone mineral content (kg)—Whole-body			
BIA DXA	2.7 ± 0.4 2.7 ± 0.3	0.0	0.137	2.311	0.062
		Fat mass (kg)—Right arm			
BIA DXA	0.9 ± 0.7 1.1 ± 0.6	0.2	0.233	1.475	0.400
		Fat mass (kg)—Right leg			
BIA DXA	2.4 ± 1.1 5.7 ± 2.7	3.3	<0.001 *	65.491	0.658
		Lean mass (kg)—Right arm			
BIA DXA	2.2 ± 0.4 1.8 ± 0.3	0.4	<0.001 *	78.658	0.692
		Lean mass (kg)—Right leg			
BIA DXA	7.5 ± 1.1 6.6 ± 1.3	0.9	<0.001 *	22.644	0.438

SD: standard deviation, η_p^2: partial eta squared values, BIA: bio-electrical impedance analysis, DXA: dual-energy X-ray absorptiometry, *: significant differences (p < 0.05) between BIA and DXA.

Overall, significantly lower values for whole-body fat%, whole-body fat mass and right leg fat mass together with significantly higher values for whole-body lean mass, whole-body bone mineral content and right arm lean mass were observed using BIA against DXA in men. No significant differences were found for fat mass in the right arm and lean mass of the right leg among men.

In women, significantly lower values for whole-body fat%, whole-body fat mass and right leg fat mass were complemented by significantly higher values for whole-body lean mass, right arm lean mass and right leg lean mass using BIA against DXA. No significant differences were observed for whole-body bone mineral content and fat mass in the right arm among women.

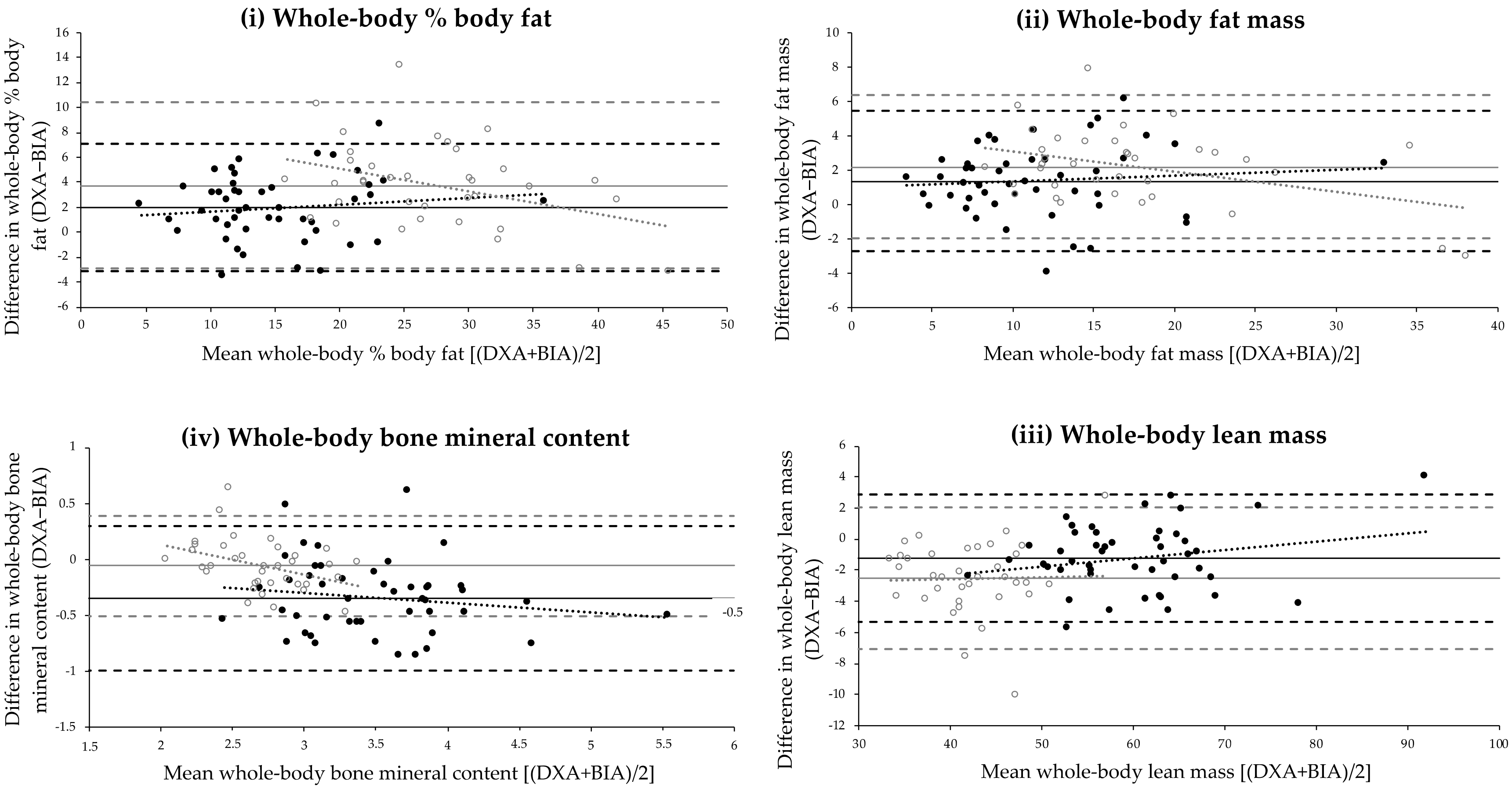
Pearson's r correlation coefficients between the BIA and DXA outcome measures are shown in Table 4. All presented correlation coefficients indicated statistically significant ($p < 0.05$) and moderate to very strong positive relationships ($r \geq 0.80$), except for those expressing the association between BIA and DXA right arm fat mass (men: $p = 0.904$, women: $p = 0.130$) and right leg fat mass (only in men: $p = 0.845$). Based on the Fisher r-to z-transformation, a significant difference between the men's and women's BIA-DXA correlation coefficients was found for the measurement of both whole-body lean mass, right leg fat mass and right arm lean mass. These Pearson's r correlation coefficients were significantly higher in men than in women (whole-body lean mass: Pearson' r difference = 0.06, right arm lean mass: Pearson' r difference = 0.26), apart from the right leg fat mass, with lower values being observed in men versus women (Pearson' r difference = 0.14).

Table 4. Pearson's r correlation coefficients between BIA and DXA outcome measures for men and women separately.

	Men **(n = 47)**	**Women** **(n = 36)**	**Fisher r- to z-Transformation** ***p*-Value** **(Z-Value)**
Body fat (%)—Whole-body	0.90 ^{*,e}	0.90 ^{*,e}	1.00 (0.00)
Fat mass (kg)—Whole-body	0.93 ^{*,e}	0.96 ^{*,e}	0.21 (−1.25)
Lean mass (kg)—Whole-body	0.97 ^{*,e}	0.91 ^{*,e}	0.01 (2.45) *
Bone mineral content (kg)—Whole-body	0.85 ^{*,d}	0.81 ^{*,d}	0.58 (0.56)
Fat mass (kg)—Right arm	−0.018 ^{a}	0.26 ^{a}	0.22 (−1.23)
Fat mass (kg)—Right leg	−0.029 ^{a}	0.43 ^{*,b}	0.03 (−2.12) *
Lean mass (kg)—Right arm	0.87 ^{*,d}	0.61 ^{*,c}	0.01 (2.71) *
Lean mass (kg)—Right leg	0.80 ^{*,d}	0.65 ^{*,c}	0.16 (1.40)

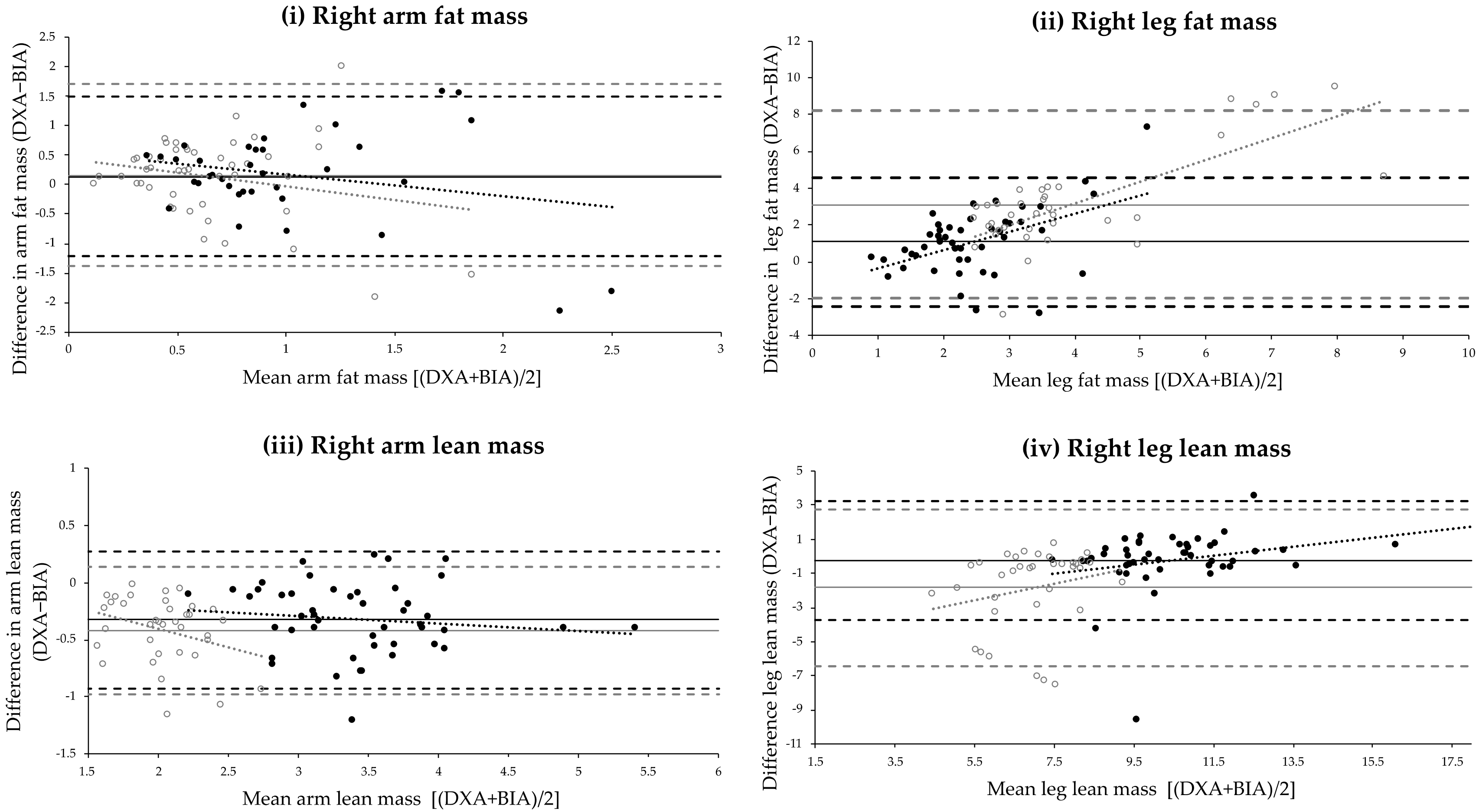
BIA: bio-electrical impedance analysis, DXA: dual-energy X-ray absorptiometry, *: p-values < 0.05, ^{a}: negligible correlation (r < 30), ^{b}: weak correlation (r = 0.30–0.50), ^{c}: moderate correlation (r = 0.50–0.70), ^{d}: strong correlation (r = 0.70–0.90), ^{e}: very strong correlation (r > 90).

The degree of agreement between the two different body composition assessment methods was evaluated using Bland–Altman plots according to the participant's sex for whole-body and segmental outcome measures, respectively (Figures 1 and 2). For all outcome measures, there was a significant difference between the mean difference and zero ($p < 0.001$), indicating a significantly lower value for whole-body fat%, whole-body fat mass and right leg fat mass as well as higher values for whole-body bone mineral content (only in men), right arm lean mass, right leg lean mass (only in women) in BIA compared to DXA. No significant difference was observed for right arm fat mass ($p = 0.09$) and right leg lean mass ($p = 0.423$) in men, in addition to right arm fat mass ($p = 0.116$) and whole-body bone mineral content ($p = 0.069$) in women.



●: men, ○: women, ━ : mean in men, ━ : mean in women, ‒ ‒ : upper and lower limits of agreement in men (± 1.96 SD), ‒ ‒ : upper and lower limits of agreement in women (± 1.96 SD), ⋯⋯ : trendline in men, ⋯⋯ : trendline in women, BIA: bio-electrical impedance analysis, DXA: dual energy X-ray absorptiometry

Figure 1. Bland–Altman plots showing the mean value plotted against the mean difference (DXA vs. BIA) for whole-body outcome measures.



● : men, ○ : women, ▬ : mean in men, ▬ : mean in women, ‒ ‒ : upper and lower limits of agreement in men (± 1.96 SD), ‒ ‒ : upper and lower limits of agreement in women (± 1.96 SD), ... : trendline in men, ... : trendline in women, BIA: bio-electrical impedance analysis, DXA: dual energy X-ray absorptiometry

Figure 2. Bland–Altman plots showing the mean value plotted against the mean difference (DXA vs. BIA) for segmental outcome measures.

4. Discussion

The present study compared body composition test outcomes from the InBody S10 BIA device and Norland Elite DXA both at the whole-body and segmental level (i.e., right arm and right leg) in young healthy men and women.

Our results showed that BIA yielded significantly lower whole-body fat% and whole-body fat mass values but higher whole-body lean mass values compared to DXA, regardless of the participant's sex. The Bland–Altman plots supported this finding by consistently demonstrating lower body fat% and whole-body fat mass values as well as higher whole-body lean mass values against DXA outcomes in both male and female young healthy adults. In turn, strong to very strong positive correlations for all whole-body outcome measures were observed, with a significantly stronger correlation in men than women for lean mass in particular. Specifically in men, significantly higher values in bone mineral content were also observed in BIA compared to DXA, whereas in women, no significant difference was found between the two body composition assessment methods.

Although comparison with previous literature is challenging due to the use of different devices and study populations, the findings of the current study are more or less in agreement with the results of previous work in a similar study population in terms of age [16,23–25]. However, our results contradict those of the study performed by Jayanama et al. [26] in which no significant difference was found between the Inbody S10 and the Hologic Discovery DXA for whole-body fat%, whole-body fat mass and whole-body fat-free mass, regardless of sex. Likewise, our results are inconsistent with the study performed by Anderson et al. [17] as their linear regression analysis revealed good agreement between a multifrequency BIA (i.e., Inbody 520 and 720) and DXA (i.e., Biospace) for whole-body fat mass and fat-free mass. This discrepancy in findings may in part be related to the differences in study population. Jayanama et al. [26] included hemodialysis patients instead of healthy participants, whilst the study of Anderson et al. [17] consisted of somewhat older participants (i.e., 27 $\pm$ 6 years) with a higher BMI (i.e., 25.8 $\pm$ 4.5 kg/m^2) compared to the participants in the present study sample. In accordance with the current study, previous research showed that BIA provided lower body fat% values and higher whole-body fat-free mass values in normal weight participants but higher body fat% values and lower whole-body fat-free mass values in obese participants when compared to DXA [27].

In recent years, segmental body composition has gained more attention because of its link with health, sport performance and injury risk [4,5]. However, to date, the level of agreement between the segmental analysis of BIA and DXA body composition estimates in both sexes remains largely unclear. In this respect, our innovative study showed no significant difference in segmental fat mass of the right arm between BIA (i.e., Inbody S10) and DXA (i.e., Norland Elite) for both men and women, whereas both sexes displayed significantly lower right leg fat mass values in BIA compared to DXA. These results were accompanied with negligible to weak correlation coefficients and are partially in line with the results reported by Wingo et al. [28]. Despite the strong to very strong correlations between body composition assessment methods, this latter study showed significantly lower fat mass and higher lean mass values in BIA (i.e., Quantum IV) compared to DXA (i.e., Lunar iDXA) in both the right arm and right leg. However, it should be noted that this study by Wingo et al. [28] only analyzed the level of agreement of a mixed sample in terms of participant sex (i.e., including both men and women). Instead, Nickerson [23] investigated sex-specific segmental body composition differences between BIA and DXA in 28 men and 45 women and demonstrated significant lower fat mass using the Quantum IV BIA against the GE Lunar Prodigy DXA both in the arms and legs among men. This latter study also showed that for women a significant lower fat mass was only apparent in the legs. A possible explanation of the disparity in results for fat mass in the arm according to sex may be related to the use of different BIA and DXA devices. More specifically, Wingo et al. [28] and Nickerson [23] used a single-frequency BIA (i.e., 50 kHz) whereas more recent devices such as the Inbody S10 apply six frequencies for estimating body composition. These recent devices allow more accurate body composition estimates (i.e., particularly regarding intra- and extra cellular fluids) [29].

The present study is novel in its use of more recently developed body composition assessment devices that also enable the analysis of segmental body composition. To the best of our knowledge, our study is the first to compare both specific BIA and DXA assessment devices in young healthy adults. Nevertheless, our study also contains some limitations. First, this study was exclusively conducted with Caucasian healthy young adults aged between 18 and 24 years. Therefore, the findings are age and population specific and could not be generalized across other age and ethnic groups, due to body composition variability observed between ethnicities [30]. Second, the participants' actual hydration statuses were not assessed in the current study because of practical reasons. Although the participants followed a strict (pre-)test protocol, such as no alcohol consumption 24 h prior to testing and voiding their bladder, their actual hydration status may have impacted the BIA estimations. Third, our study results might have been influenced by external factors, such as the ambient temperature, humidity and circadian rhythm (i.e., individual measurements were carried out between 8:45 and 16:15), which were not taken into account. A last consideration is that, due to time constraints related to the DXA research scans, only the body composition of the right arm and leg segments were measured in this study. Therefore, we were not able to identify the agreement between BIA and DXA for monitoring bodily asymmetries.

5. Conclusions

Overall, the significant differences in segmental and whole-body composition outcomes (i.e., body fat%, fat mass, lean mass and bone mineral content) between the Inbody S10 BIA and Norland Elite DXA indicate that both methods are not to be used interchangeably. However, the moderate to very strong Pearson's correlation coefficients between both devices for body composition assessment suggest that the Inbody S10 device may be a useful alternative to the Norland Elite DXA scanner, especially for estimating leg lean mass in men and whole-body bone mineral content in women. Researchers and clinicians must weigh the practical considerations of their assessment needs with the limitations of the body composition assessment method. Despite these advancements in knowledge, it should be emphasized that additional research is still required to determine the degree of agreement in (segmental) body composition outcome measures between the InBody S10 BIA device and the Norland Elite DXA. Future research should also examine their ability and sensitivity to track changes in body composition over time in heterogeneous samples varying in ethnicity, age, trained status and adiposity.

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Data Availability Statement: All data are available from the corresponding author upon reasonable request.

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