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A COMPARISON OF BODY COMPOSITION MEASUREMENTS IN COLLEGE STUDENTS USING THREE ASSESSMENT DEVICES

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Mora JC, et. al. Dual-energy X-ray absorptiometry (DXA), bioimpedance spectroscopy (BIS), and ultrasound (US) are commonly used to estimate body composition, but each method has limitations. This study compared the body composition estimations of the three devices in college students. Ten males (23.7 ± 1.9 years; 171.9 ± 6.7 cm; 81.8 ± 11.4 kg) and twenty females (23.1 ± 1.9 years; 161.8 ± 6.1 cm; 64.9 ± 15.3 kg) volunteered. Pearson correlation coefficients between the devices were strong. Body fat percentage estimations for the DXA, BIS, and US were 30.6 ± 9.2, 28.3 ± 9.1, and 22.8 ± 8.1 respectively. The ANOVA revealed a difference in body composition between the devices and Tukey's post hoc tests identified that there was a statistically significant difference between the BIS and the US and the US and DXA, but not between the BIS and DXA. The level of agreement (LOA) was wide between the DXA and US (mean difference 7.8, LOA between 0.23 and 15.4) and between the BIS and US (mean difference 5.4, LOA between -3.4 and 14), but narrower between the BIS and DXA (mean difference 2.4, LOA between -4.2 to 9). When comparing changes in body composition, it is best to utilize the same device to minimize the error in the reported differences in body composition. Future studies should compare the body composition estimation from these devices to a more accurate multi-compartment model to help determine their accuracy in college students.

Key Words: dual-energy X-ray absorptiometry (DXA), bioimpedance spectroscopy (BIS), ultrasound, body fat

INTRODUCTION

Body composition is considered one of the five health-related components of physical fitness according to the American College of Sports Medicine (Liguori, 2018). Excess body fat has been shown to increase the risk of developing coronary artery disease, hypertension, stroke, peripheral artery disease, type II diabetes, and other medical problems (Jia, Wang, Jiang & Pan, 2010; Steinberger & Kelly, 2006). Collectively, these medical conditions that partly result from excess body fat may lead to an increased risk of morbidity and mortality (Masters et al., 2013). By increasing validity and reliability between body composition studies, standardized body composition analysis can potentially be used more regularly in various settings. Currently, most medical offices use a formula which calculates body mass index (BMI) as a reference to make health recommendations for their patients. This technique can be inaccurate because it only uses height and weight to assess an individual and does not differentiate between fat mass and fat-free mass; this can lead to improper health recommendations. Body composition assessments look at the various components that make up the body and give better insight on the health status of an individual when compared to BMI (Goonasegaran, Nabila & Shuhada 2012).

DXA is commonly used to estimate body composition in clinical and research settings. Currently, DXA is considered the gold standard for detecting osteoporosis (Pisani et al., 2013) and uses low energy X-ray beams to assess bone mineral density and estimate body composition; the X-rays are absorbed at different rates depending on the tissue it travels through and these rates are used to differentiate between tissues of the body. DXA uses a three-compartment model and compartmentalizes the body into bone mineral content, lean mass (not including bone), and fat mass (Withers et al., 1998). Hydration status is a limitation of DXA since the device makes the assumption that lean tissue has a fixed amount of water (Kuriyan, 2018). Another limitation with DXA is the estimation of the composition of soft tissue in bone mineral-containing pixels (Tothill & Nord, 1995). Lastly, DXA equipment is costly and requires advanced training which may include possession of a limited X-Ray technician license to operate the device in some states. DXA has been reported to make body composition estimates questionable at the individual level among muscular physique athletes due to the large limits of agreement that the device produces (Graybeal, Moore, Cruz & Tinsley, 2018).

BIS is another method commonly used to estimate body composition and uses a two-compartment model that divides the body into fat mass and fat free mass (Rush, Chandu & Plank, 2006). BIS has been reported to produce valid TBW estimates in resistance-trained males as compared to deuterium dilution and uses modeling techniques to predict body fluids (Kerr, Slater, Byrne & Chaseling, 2015; Moon, 2013). Once the modeled body water value is predicted, the BIS technology uses prediction equations to estimate body composition value; various prediction equations are available to use and they are derived from a particular population with certain traits. Hence, limitations of the impedance-based devices include sex, age, disease state, race and/or ethnicity (Rush et al., 2006). Hydration status can also affect the body composition results (Saunders, Blevins & Broeder, 1998). Similar to the DXA, the BIS has been reported to make body composition estimates questionable at the individual level among muscular physique athletes due to the large limits of agreement that the device produces (Graybeal et al., 2018).

US is also used to estimate body composition and uses a two-compartment model that divides the body into fat mass and fat-free mass. A-mode, or amplitude mode, US has been reported to provide accurate estimations of body composition in athletic and normal weight populations (Pineau, Guihard-Costa & Bocquet, 2007; Pineau, Filliard & Bocquet, 2009), but to under predict body fat percentage and fat mass in overweight and obese men and women (Smith-Ryan, Fultz, Melvin, Wingfield & Woessner, 2014). A-mode US uses a single beam in a single plane where a pulse is applied at a speed of sound in the tissue; the beam determines the acoustic reflection and impedance of different tissue borders and the software of the device estimates the thickness of the subcutaneous adipose tissue (Da Silva, 2010). Subcutaneous adipose tissue at specific landmarks have been shown to be correlated with subcutaneous adipose tissue throughout the body; various formulas are available for specific populations to estimate body density based on the subcutaneous fat measurements (Lohman, 1991). The Siri equation can then be used to estimate body fat percentage based on the estimated body density (Fanelli, Kuczmarski & Hirsch, 1988). Ultrasound is practical because it is portable and requires non-invasive procedures, but sources of subcutaneous fat measurement errors have been reported such as errors in sound speed for the same site and person and compression of fat tissue (Smith-Ryan et al., 2014). Furthermore, since individuals distribute body fat differently, the assumption that there is a constant ratio between subcutaneous fat and overall body fat may lead to measurement errors with this device (Lohman, 1991).

Due to the limitations and potential measurement errors when estimating body composition with the DXA, BIS, and US, the purpose of this study was to estimate the body composition measurements of the three devices and compare them to each other for level of agreement on healthy college age students. Previous investigations have compared body composition estimations for various populations between the US and DXA, BIS and DXA, and between DXA/BIS/US and multi-compartment body composition models (Pineau et al., 2007; Graybeal et al., 2018; Smith-Ryan et al., 2014); however, to the authors' knowledge the body composition estimations of the DXA, A-mode US, and BIS have not been compared with a healthy college student population.

METHODS

Participants and Assessment Devices

Ten males (23.7 ± 1.9 years; 171.9 ± 6.7 cm; 81.8 ± 11.4 kg) and twenty females (23.1 ± 1.9 years; 161.8 ± 6.1 cm; 64.9 ± 15.3 kg) signed an informed consent approved by the university's Institutional Review Board and volunteered for this investigation. Participants reported to the laboratory after ≥ 8 hours of abstaining from exercise, eating, drinking, smoking, supplement, or drug consumption. After completing the informed consent and basic health history questionnaire to ensure they qualified to participate in the study (i.e., no metal implants, pacemaker, etc.), height was measured with a stadiometer (Seca 213, Seca North America, CA) and weight was measured with a digital electric scale (Tanita BWB-800S, Tanita Corporation of America Inc., IL). The body composition assessments (BIS, US, DXA) were all done on the same day within a 2-hour window in order to prevent differences in conditions from one device to the other as might occur if participants came in for testing on different days. Since hydration status may influence the body composition estimates of the BIS and the DXA (Saunders et al., 1998; Kuriyan, 2018), hydration status was assessed prior to measuring body composition. In order to ensure that participants were euhydrated to prevent hydration levels from impacting the body composition results, participants were asked to urinate in a cup so that the specific gravity of urine could be measured with a refractometer prior to testing body composition. Participants were required to have a urine specific gravity between 1.005 and 1.020 before continuing with the testing. Body composition was then measured in this order using the three devices: 1) Impedimed SFB7 BIS (Queensland, Australia), 2) Intelametrix BodyMetrix BX-2000 A-mode US (Livermoore, CA), and 3) GE Lunar iDXA (Madison, WI).

Procedures

The BIS was performed as per manufacturer instructions. The machine was calibrated and the researchers ensured that the device passed the calibration test. Participants were placed in a supine position for approximately ≥ 3 minutes on a non-conductive surface with the arms and legs not touching while the researcher prepped the participant for the BIS analysis. Two electrodes were placed at the left hand on the midline of the ulnar styloid process on the wrist and the distal electrode 5 cm down towards the fingers in a similar manner. The other two electrodes were placed on the left ankle between the medial and lateral malleolus bones and the distal electrode down towards the toes in a similar manner 5 cm apart. Lastly, the researcher input the participant's height, weight, age, and sex into the BIS system and ran the BIS analysis.

After the BIS assessment, the BodyMetrix A-mode US device was used to assess body composition as per the manufacturer recommendations. The US probe was attached by USB to a MS Surface (Microsoft, Redmond, WA) with the corresponding software (BodyView Professional Software). The researcher input the participant's height, weight, age, and sex into the program. Measurements were taken on the right side of the body while the participant was standing using the three-site locations according to Jackson, Pollock & Gettman (1978) and as instructed on the screen by the software. The measurements included the triceps, suprailiac, and thigh for women and the chest, abdomen, and thigh for men. The trained researcher first placed gel on the head of the probe and then slid the probe ±5 millimeters across the site without losing contact with the skin and ensuring minimal tissue deformation. Each site was measured two to three times based on the software's agreement between measurements; the average of these trials was used to identify the final subcutaneous thickness measurement. Once the fat thickness was recorded for each of the 3 anatomical sites, the device software estimated the body fat percentages.

After completing the BIS and US measurements, the DXA total body scan was performed. Prior to initiating any data collection with the DXA, the GE phantom was used as a quality control tool as per manufacturer recommendations to ensure that the DXA passed the quality control test. Participants were asked to lie down on the DXA table in a supine position centered on the table within the scanning area with hands placed at the side of the legs. Velcro straps were placed around the ankles and knees so that the participant would not have to hold their feet together for the duration of the scan. Participants were instructed to remove any metal objects (i.e., jewelry) prior to initiating the scan and to remain as still as possible while the scan was conducted. After the scan, EnCORE software version 17 (GE Healthcare, Madison, WI) was used to analyze the region of interest and estimate the bone mineral content, percent fat, lean tissue mass, and fat mass.

Statistical Analysis

All statistical analyses were performed using SPSS statistics software. A Pearson correlation was performed to examine the correlations in body composition estimations between the three devices. A one-way Analysis of Variance (ANOVA) with Tukey's Post-hoc tests was also performed to determine if there was a difference between the body composition measurements between the devices. Bland-Altman analysis was used to evaluate the limits of agreement (LOA) between the devices.

RESULTS

The Pearson correlation coefficients between all three devices were strong for the BIS and US (r = 0.870, p < 0.01, Figure 1), for the BIS and DXA (r = 0.932, p < 0.01, Figure 2), and for the US and DXA (r = 0.915, p < 0.01, Figure 3). Body fat percentage measures for the DXA, BIS, and US were 30.6 ± 9.2, 28.3 ± 9.1, and 22.8 ± 8.1, respectively as shown in Figure 4. The ANOVA revealed there was a statistically significant difference in body composition results between the devices ($F_{2, 89}$ = 6.161, p = 0.003) and Tukey's post hoc tests identified that there was a statistically significant difference between the BIS and the US ($p \leq 0.05$) and the US and DXA (p ≤ 0.03), but not between the BIS and DXA (p = 0.558). The Bland-Altman analysis (Table 1) disclosed the LOA was wide between the DXA and US (mean difference 7.8, LOA between 0.23 and 15.4) and between the BIS and US (mean difference 5.4, LOA between -3.4 and 14), but the LOA was closer between the BIS and DXA (mean difference 2.4, LOA between -4.2 to 9).

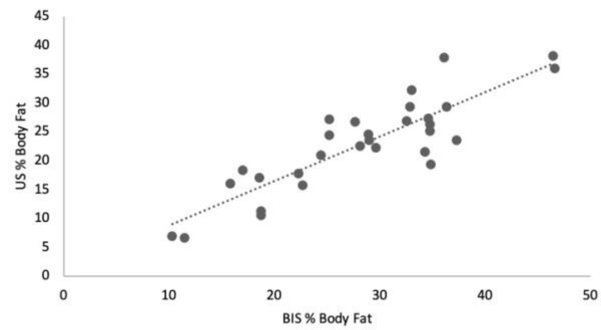

Figure 1. Correlation for Bioimpedance Spectroscopy (BIS) vs Ultrasound (US) for Body Fat %.

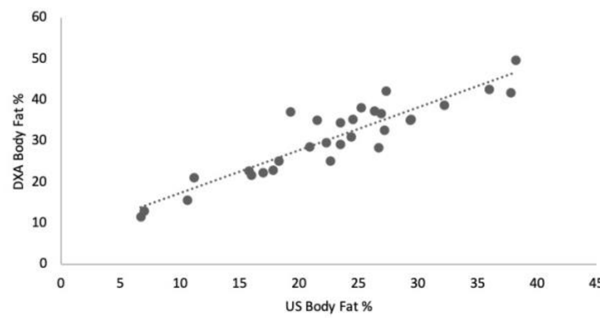

Figure 2. Correlation for Ultrasound (US) vs Dual X-ray Absorptiometry (DXA) for Body Fat %.

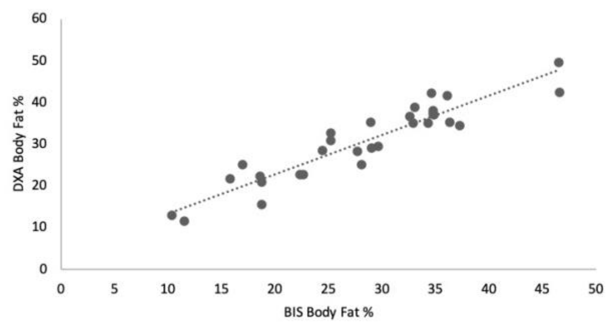

Figure 3. Correlation for Bioimpedance Spectroscopy (BIS) vs Dual X-ray Absorptiometry (DXA) for Body Fat %.

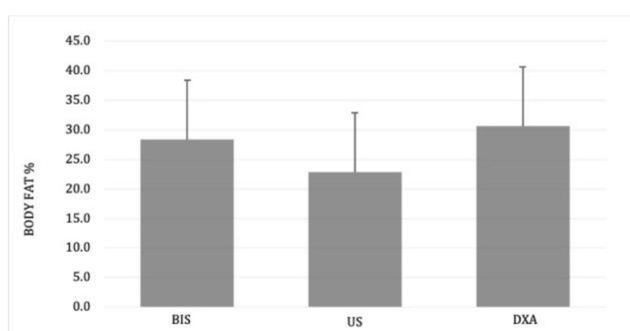

Figure 4. Mean Body Fat % for Bioimpedance Spectroscopy (BIS), Ultrasound (US) and Dual X-Ray Absorptiometry (DXA).

Table 1

Bland-Altman Agreements for Body Fat % Estimates

Body Composition Device	Mean Difference	95%CI	Limit of Agreement
DXA vs US	7.8	6.4 to 9.2	0.23 to 15.4
BIS vs US	5.4	3.8 to 7.0	-3.4 to 14
DXA vs BIS	2.4	1.2 to 3.6	-4.2 to 9

Note. * significant difference between BIS and US. # significant difference between DXA and US.

DISCUSSION

This study showed a significant difference between the US when compared to the BIS and DXA. In agreement with the results of this investigation, Smith-Ryan et al. (2014) reported that the A-mode US under predicted the body fat percentages of overweight or obese participants. Specifically, the results of this investigation revealed that the body fat percentages of the A-mode US were significantly lower (22.8 ± 8.1) than that of the DXA (30.6 ± 9.2) and the BIS (28.3 ± 8.1). Additionally, there was a wide LOA in this investigation between the DXA and US and between the BIS and US, but a narrower LOA between the BIS and DXA.

A study by Molfino, Don and Kaysen (2012) also reported similar findings to this investigation when comparing the body composition results of the BIS and DXA among hemodialysis patients. In both studies, no statistical differences were reported between the body composition estimations between the DXA and the BIS. Although the DXA devices used in this investigation and the hemodialysis study differed, the results reported in both investigations were consistent.

In contrast to the findings of this investigation, Pineau, Lalys, Pellegrini and Battistini (2013) found no statistically significant differences in body fat assessment when comparing an ultrasound-based device to a Discovery A Model DXA (p = 0.20). However, varying results should be expected due to differences in methodology. Differences in body composition estimates between DXA devices are expected due to differences in calibration, software, and scanning speed (Black et al., 2002). The US devices and measurement sites also differed between studies. Pineau et al. (2013) assessed subcutaneous fat thickness at the posterior abdominal wall and mid-thigh (right and left) using B-Mode US. Conversely, this study used A-mode US and estimated body composition with a three site Jackson, Pollock, & Gettma's method (1978). Due to different devices, regression equations, and landmarks being assessed, varying results are expected.

The main limitations to this investigation were a small sample size and a lack of comparison in body fat estimations to a more accurate multi-compartment model. In future research, more participants can be tested and compared to a multi-compartment model to further assess the reliability and validity of the devices with various populations. Multi-compartment models can take body mass, body volume, total body water, and bone mineral content to estimate body composition more accurately. The four-compartment model is currently accepted as an accurate method for estimating body composition and is often used as a criterion standard (Westerp, 2008; Graybeal et al., 2018). Comparing body composition assessment devices to the four-compartment model can help investigators to calculate the measurement error of each device due to their respective limitations.

CONCLUSION

Although there is a strong positive correlation for body composition between the BIS, US, and DXA, there is a significant difference in the body composition estimations between the DXA and US and the BIS and US. There is a wide LOA between the DXA and US and between the BIS, but a narrower LOA between the BIS and DXA. Body composition analysis is used in various settings that include research, healthcare and sport performance facilities. When comparing changes in body composition, it is best to utilize the same device to minimize the error in the reported differences in body composition. Knowledge on how to minimize error can help practitioners make better informed decisions.

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