Published in final edited form as:

Clin Nutr ESPEN. 2018 December ; 28: 141–147. doi:10.1016/j.clnesp.2018.08.013.

Comparison of segmental body composition estimated by bioelectrical impedance analysis and dual-energy X-ray absorptiometry

Brooks C. Wingo, PhD*,

Assistant Professor, Department of Occupational Therapy, University of Alabama at Birmingham, 1720 2nd Ave S. Birmingham, AL 35294, 205-934-5982

Valene Garr Barry, BS,

Graduate Student Trainee, Department of Nutrition Sciences, University of Alabama at Birmingham, 1720 2nd Ave S. Birmingham, AL 35294, 205-996-4062

Amy C. Ellis, PhD, RD, and

Assistant Professor, Department of Nutrition and Hospitality Management, University of Alabama, 412 Russell Hall, Box 870311 Tuscaloosa, AL 35487, 205-348-8128

Barbara A. Gower, PhD

Professor, Department of Nutrition Sciences, University of Alabama at Birmingham, 1720 2nd Ave S. Birmingham, AL 35294, 205-934-4087

Abstract

Background & Aims: Segmental body composition may be an important indicator of health and nutritional status in conditions where variations in fat and lean mass are frequently isolated to a particular body segment (e.g. paralysis, sarcopenia). Until recently, segment-specific body composition could only be assessed using invasive and expensive methods such as dual-energy x-ray absorptiometry (DXA), magnetic resonance imaging (MRI), or computed tomography (CT). Bioelectrical impedance analysis (BIA) may be a rapid, inexpensive alternative for assessing segmental composition, but it has not been fully validated for this purpose. The purpose of this study was to compare segmental estimates of lean and fat mass using BIA versus a criterion standard of DXA.

*Corresponding author, 1720 2nd Ave S., SHPB 385, Birmingham, AL 35294, 205-934-5982, bcwingo@uab.edu, vgarr@uab.edu, aellis@ches.ua.edu, bgower@uab.edu.

Statement of Authorship:

Conception and design: BW, AE, BG

Collection and assembly of data: BW, VGB

Data analysis and interpretation: All authors

Manuscript writing: All authors

Final approval of manuscript: All authors

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Conflicts of Interest:

There are no conflicts of interest to report.

Methods: A cross-sectional pilot study was conducted in n=30 healthy adults. Outcome measures included total mass, fat mass and lean mass of arm, leg and trunk. Pearson correlation coefficients (r) and paired-samples t-tests (t) were used to assess relationships between each outcome as measured by BIA and DXA.

Results: Although the methods were strongly correlated for all measures, ($r > .87$ for all segments) BIA routinely overestimated lean mass for arm and trunk (mean difference arm: 0.97 kg, $p = .008$; trunk: 5.58 kg, $p < .0001$); and underestimated fat mass for arm and leg (mean difference arm: 0.42 kg, $p < .0001$; leg: 1.94 kg $p < .0001$). BIA overestimated total body lean mass in 93% of participants and underestimated total body fat mass in 90% of participants.

Conclusions: Significant discrepancies were noted between DXA and BIA in all body segments. Further research is needed to refine BIA methods for segmental composition estimates in heterogeneous samples and disease-specific populations before this methods can be used reliably in a clinical setting.

Keywords

Body weights and measure; obesity; sarcopenia; muscle atrophy

INTRODUCTION

Assessment of body composition is an important aspect of clinical nutrition assessment and tracking changes in body composition over time can be an informative means of assessing disease state/progression.¹ Clinical populations including individuals with paralysis or lipodystrophy highlight the difficulty in assessing weight-related risk using traditional clinical assessments such as body mass index (BMI) or waist circumference. These groups frequently experience variations in fluid, adiposity and lean mass that may be isolated to a particular body segment, and this isolation may lead to underestimation of risk when traditional clinical assessments are used.² For example, use of BMI in older adults may underestimate risks of sarcopenia.^{3,4} The increase in central adiposity along with the decrease in height commonly seen with aging may mask the loss of appendicular lean mass characteristic of sarcopenia.⁵ Without a means of selectively measuring arm and leg composition, the risk of frailty and muscle loss may be overlooked. Segmental assessment could also be beneficial in rehabilitation settings where muscle atrophy and redistribution of adipose tissue can impair gait, increase risk of falls, and increase risk of rehospitalization.⁶⁻⁸ Thus, a method to differentially quantify lean and fat mass in arms, legs, and trunk regions in a clinical setting would allow dietitians and other healthcare professionals to better assess risk.^{9,10} Currently, the only reliable methods of assessing segmental body compositions include dual-energy X-ray absorptiometry (DXA), magnetic resonance imaging (MRI), and computed tomography (CT), which are expensive, may present excessive burden including discomfort and exposure to ionizing radiation, and frequently are not available for assessment of body composition in clinical settings.^{1,11} Developing accurate and affordable means of assessing body composition in particular body segments most impacted by a disease may lead to improvements in nutritional assessment and tracking of disease progression over time.

Bioelectrical impedance analysis (BIA) is commonly used for assessing total body composition in clinical and community wellness settings due to its rapid, non-invasive methods that are relatively inexpensive and widely accessible. BIA estimates body composition using an undetectable electrical current passed through the body to estimate the volume of compartments based on conductivity. Body tissues that are aqueous with dissolved electrolytes (e.g., muscle) are good conductors of the electrical current, whereas tissues such as fat and bone that are non-aqueous are poor conductors. The resistance of the current can be used to estimate total body water, which in turn can be used to estimate lean mass and fat mass.^{9,10}

BIA prediction equations were initially based on the assumption that the body is a cylinder, with relatively normal distribution of body tissues and fluid throughout. This often led to inaccurate estimations of body composition.¹² This limitation has purportedly been overcome by introduction of segmental estimation. Segmental estimation calculates resistance values of legs, arms, and trunk from half-body resistance measures and uses these values to estimate body composition using regression equations to predict total, lean, and fat mass.⁹ Although many BIA instruments on the market now utilize segmental BIA, independent segmental measures have not been widely validated for use other than as a means of estimating total body composition.¹³

The purpose of this study was to establish preliminary validity of measures of total mass, lean mass, and fat mass within the arms, legs and trunk from an 8-lead, prone BIA when compared to dual-energy x-ray absorptiometry (DXA) in a small sample of healthy adults. While DXA is an estimate rather than direct measure of body composition, it has been validated against CT, and is widely used in research as a criterion measure of total and regional body composition.^{14–19} This is the first step in a series of studies that will validate these measures in populations with variations in body composition due to disease states.

MATERIALS AND METHODS

Participants were 30 healthy white adults (53% female), ages 18 to 65 years recruited from the University of Alabama at Birmingham campus and surrounding Birmingham area between September 2015 and March 2016. Participants were recruited through flyers posted around the university campus and word of mouth. Eligibility criteria for enrollment included: (a) BMI 18–50 kg/m², (b) non-smokers, and (c) able to lie flat, sit and stand as required for testing. Individuals were excluded from participating for the following reasons: (a) amputation, (b) electrical or metallic implants such as cardiac pacemaker, (c) pregnant or breastfeeding, (d) extensive tattoos (covering more than 1/3 of the arms, legs, or back), (e) overt signs of edema or dehydration. Forty-five individuals were screened for eligibility; thirteen were ineligible and two cancelled prior to their study visit. The University of Alabama at Birmingham Institutional Review Board approved the study (protocol number 150701003) and all participants provided written informed consent prior to testing.

All measures were completed in the University of Alabama at Birmingham Department of Nutrition Sciences during a single visit. Prior to testing, participants were asked to fast (no food or drink except plain water) for 10 hours prior to testing, avoid drinking alcohol within

24 hours of testing, avoid exercise or sauna use within 12 hours of testing, and refrain from using hand or body lotion the morning of the testing.

Measures

Height.—Height was measured to the nearest 0.1cm with shoes removed using a digital wall-mounted stadiometer (Seca North America, Chino, CA).

Body mass.—Body mass was obtained to the nearest 0.1 kg in minimal clothing on a digital platform scale (Seca North America, Chino, CA) calibrated for accuracy within 0.1 kg.

Body Mass Index.—Body Mass Index (BMI) was computed as kg/m^2 using data from the participant's height and weight.²⁰

Limb length and circumferences.—Total arm length was measured in cm from the posterior border of the acromion process to the distal radioulnar joint. Upper arm length was measured from the posterior border of the acromion process to the tip of the olecranon process. The midpoint of the upper arm was marked, and the circumference was measured at this point. Total leg length was measured from the iliac crest to the lateral malleolus. Waist circumference was measured midway between the lowest rib and the uppermost border of the iliac crest at the end of normal expiration. All measures were collected using a non-elastic tape measure.²¹ All measures were recorded once and a single staff person collected all body measurements on all participants.

Total Body Water.—Total body water was measured using deuterium dilution. Participants provided a baseline urine sample and second sample four hours after consuming a galvanically-weighed 10 g dose of 99.9% deuterium orally.

Bioelectrical impedance analysis (BIA).—Bioelectrical impedance analysis was assessed using an RJL© Systems Quantum IV eight-lead 12-channel isolated switch BIA (RJL, Clinton Township, MI). The BIA equipment was calibrated prior to each participant visit. Leads were attached via electrode at the hands (mid dorsum of hand just proximal to metacarpal phalangeal joint line), wrists (mid dorsum of the wrist centered on a line joining the bony prominence of radius and ulna), ankles (mid anterior ankle centered on a line joining the bony prominence of the medial and lateral malleoli) and feet (mid dorsum of the foot just proximal to the metatarsal of the phalangeal joint line) while participants were lying in a prone position on a non-conductive exam table. This technique enables segmental impedance measurement of the right arm, the left arm, the trunk, the right leg, the left leg and the right and the left body side. Arm and leg segments were calculated as the sum of right and left measures of each component (i.e. arm fat mass= right arm fat mass +left arm fat mass). Resistance (R) and reactance (Xc) values were recorded to the nearest 0.1Ω. Impedance was measured with a current of 100 μA at a single frequency of 50 kHz. The same tester took each measure three times, and the mean of the three measures was used in prediction equations. Prediction equations from the manufacturer were used to calculate fat mass and lean mass of each segment and total body to the nearest 0.001 kg.

Dual Energy X-ray Absorptiometry (DXA).—Dual-energy X-ray absorptiometry measurements of participants' total and segmental fat and lean mass were obtained with a Lunar iDXA with enCORE software version 13.6 (GE Healthcare, Chicago, IL). The accuracy of the densitometer was verified daily by scanning the manufacturer's hydroxyapatite spine phantom of a known density. When participants did not fit within the scanning area (n=6), the enCORE software estimated missing regions automatically.²² Only the missing regions were estimated; everything inside the scan area was measured directly. For all participants, the left arm was the portion of the body estimated. All DXA scans were completed on the same scanner with the same software by a trained technician.

Statistical Analysis

Data analyses were performed with the IBM SPSS software, version 23.²³ Descriptive statistics including frequency distributions, means, and standard deviations were calculated for participant characteristics. Paired samples t-tests were used to assess if measures of total mass, fat mass and lean mass for each segment were significantly different between BIA and DXA. The level of statistical significance was set at $\alpha=0.05$. Cohen's *d* for paired samples was calculated as a measure of effect size for differences between BIA and DXA measures. An effect size of $d=0.2$ was considered a small effect size, $d=0.5$ was considered a moderate effect size and $d=0.8$ was considered a large effect size.²⁴ Pearson correlation coefficients (*r*) were used to assess the correlation between total, fat, and lean mass measured by BIA and DXA.

RESULTS

Participant characteristics are presented in Table 1. Mean percent total body water was $50\% \pm 7.63$, indicating acceptable hydration status among the sample. DXA estimated mean total body percent fat to be $32.78\% \pm 10.57$ compared to $28.45\% \pm 9.66$ estimated by BIA ($p < .001$). Total body and segmental BIA estimates of total, fat, and lean mass all had strong agreement with DXA measures, as measured by Pearson's *r* (Table 2). However, paired samples t-tests indicated that BIA significantly underestimated total mass for arm and leg segments, and underestimated fat mass for total body, arm and leg segments (Table 2). Bioelectrical impedance analysis overestimated lean mass for total body, arm and trunk, but not leg when compared to DXA.

Bland-Altman plots (Fig. 1 and 2) indicated wider than acceptable margins of agreement in all segments that appear to be a result of bias particularly at higher masses. Bioelectrical impedance analysis tended to overestimate lean mass (Fig. 1), particularly in the trunk region where the bias was 5.58 kg. This overestimation became more pronounced as mass of the respective region increased. The trend for overestimation with increased mass was statistically significant for total body lean mass ($R^2=.34$, $p < .0001$), arm lean mass ($R^2=.23$, $p=.008$) and trunk lean mass ($R^2=.44$, $p < .0001$). Conversely, BIA tended to underestimate fat mass (Fig. 2), with the same pattern of more extreme underestimation at higher masses. The trend for underestimation of fat mass at higher mass was significant for total fat mass ($R^2=.22$, $p < .005$) and leg fat mass ($R^2=.28$, $p=.003$).

Given the small sample and pilot nature of this study, bar graphs (Fig. 3 and 4) were also created to allow for a visual analysis of under and over estimates for each participant.

Graphs indicated that BIA overestimated lean mass in 93% of participants, but segment-specific overestimation varied. BIA overestimated trunk lean mass in all 30 participants, whereas leg lean mass was overestimated in 40% of participants. The graphs also indicated that BIA underestimated total body fat mass in 90% of participants. Segment-specific fat mass underestimates were greatest in the arm (80% underestimation) and leg (87% underestimation). The degree of over/underestimation varied greatly among participants, and was present in both lower and higher segment masses.

DISCUSSION

Bioelectrical impedance instruments are affordable, portable, and relatively easy to use compared to the more expensive invasive methods of DXA and MRI. As segmental BIA instruments become widely available in clinical settings, it is crucial to evaluate their accuracy and precision against the reference standards. This study aimed to explore the preliminary validity of segmental estimation of body composition measured by BIA when compared to DXA. Initial examination of correlation data indicated that BIA was strongly associated with segmental body composition when compared to DXA; however, significant mean differences in many segmental measures were observed.

It is interesting to note that the pattern of differences varied between lean mass and fat mass. Both overestimation of lean mass and underestimation of fat mass were significant for total body and arm measures; however, the trunk segment indicated only statistically significant overestimation of lean mass, whereas the leg segment showed underestimation of fat mass but not overestimation of lean mass. One explanation for this difference in leg and trunk bias may be a difference in how these segments are defined by DXA and BIA; however, total mass was not significantly different between DXA and BIA trunk measures, indicating that there are other factors contributing to the segmental differences.

Another potential explanation for the discrepancies seen in these segmental measures is that BIA uses regression methods to estimate each component individually rather than using additive or deductive methodology of distinctly measured body regions to calculate composition. This leads to a potential discrepancy between total segment mass and the sum of the segment tissue components. For example, the sum of the components for arms and trunk from BIA exceeded total mass of arms and trunk (i.e. $\text{Lean Mass}_{\text{arm}} + \text{Fat Mass}_{\text{arm}} > \text{Total Mass}_{\text{arm}}$). In contrast, with DXA, the sum of lean mass and fat mass closely approximated the total mass of each segment (i.e., $\text{Lean Mass}_{\text{arm}} + \text{Fat Mass}_{\text{arm}} \approx \text{Total Mass}_{\text{arm}}$). This may indicate that error in BIA estimation may be a result of calculation rather than a true lack of ability to detect differences in tissue mass or composition. BIA estimation may be improved by using a deductive formula similar to other methods such as the four compartment model, rather than independent regression for each segmental component.¹⁴

This study was intentionally limited to a small sample of white, generally healthy adults to minimize inter-participant variance and maximize the ability to examine the validity of individual body segments assessed by BIA vs DXA. The strong correlation found between BIA and DXA indicated that they are measuring similar body compartments, but the

significant difference in many segments indicates that further refinements may be needed for use in clinical care settings. Additional research is needed with larger, more heterogeneous samples to explore adaptations to equations that improve estimation of segmental composition, particularly in obese individuals, where BIA is known to have limited validity for whole body measures, as well as in underweight individuals, who were excluded from the current study.²⁵ Additional research is also needed in disease-specific populations, as well as different racial groups and age groups, both of which are known to have unique segmental composition.^{26–29}

The BIA methodology used in this study was an 8 lead placement on the hands and feet. This is a standard placement for many BIA methods, and this placement has been shown to have acceptable validity when compared with more proximal placement patterns when estimating total body composition.¹² Organ¹² reported that hand and foot placement yielded total body estimates equivalent with arm, leg, and trunk-specific placements. Hand/foot lead placement has many benefits including reducing the variation in placement of trunk electrodes, allowing for quick, easy measurement without the need for the patient to disrobe, and allowing for assessment of patients who are in bed or unable to stand. However, this placement may not be optimal for estimating segment-specific composition, especially in groups such as patients with spinal cord injury, who have extreme shifts in body composition. Additional research is needed to determine if segment-specific composition estimation may be improved with more proximal lead placement.

A limitation to this study that should be noted is the use of DXA as a criterion measure. Magnetic Resonance Imaging and CT are acknowledged as the true “gold standard” measures of segmental body composition; however, the cost and participant burden were outside the scope of this pilot project. DXA has been validated against CT, and is widely used in research as a criterion measure of total and regional body composition.^{14–19} Additionally, only the BIA manufacturer’s equations for estimating body composition were used in this study. Similarly, the DXA manufacturer’s equations for estimating missing body regions were used. Other equations for estimating body composition do exist, and other protocols such as scanning two sides of the body separately are available. Future validation studies should explore these options for alternative equations and scanning protocols to develop the closest possible estimation of body segments. Another limitation is the previously noted restriction to white participants. While this was necessary to increase homogeneity of this pilot sample, it limits the interpretation and generalizability of the results. Additional research is needed to validate these results in different racial groups including African Americans and Asians who are known to have different patterns of body composition from whites.

CONCLUSION

Although the results of this study suggest the segmental BIA method may provide clinically acceptable estimates of regional fat mass and lean mass among white, healthy, normal-weight adults, further research is needed to fully validate this method for clinical care. Use of individual segments may prove to be a valuable tool in monitoring disease progression, as well as nutritional status in individuals with chronic injury or disease. In addition to larger

studies with greater sample diversity, next steps of this line of research include validating BIA in disease-specific population, as well as different racial and age groups who may present with unique segmental composition. Further, if BIA is to be used as an indicator of disease progression, more research is needed to determine the reliability of detecting changes in body composition over time.

Acknowledgments

Funding: This study was supported by the University of Alabama Health Services Foundation General Endowment Fund, the National Institute of Diabetes and Digestive and Kidney Diseases [grant numbers P30DK056336 and DK079626]; the Eunice Kennedy Shriver National Institute of Child Health and Human Development [grant number K01HD079582]; and the National Institutes of Health [grant number 4R25GM086256–08].

References

1. Lemos T, Gallagher D. Current body composition measurement techniques. Current opinion in endocrinology, diabetes, and obesity 2017;24(5):310–314.
2. Nuttall FQ. Body Mass Index: Obesity, BMI, and Health: A Critical Review. Nutrition today 2015;50(3):117–128. [PubMed: 27340299]
3. Villareal DT, Apovian CM, Kushner RF, Klein S. Obesity in older adults: technical review and position statement of the American Society for Nutrition and NAASO, The Obesity Society. The American journal of clinical nutrition 2005;82(5):923–934. [PubMed: 16280421]
4. Studenski SA, Peters KW, Alley DE, et al. The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. The journals of gerontology. Series A, Biological sciences and medical sciences 2014;69(5):547–558. [PubMed: 24737557]
5. Baumgartner RN. Body composition in elderly persons: a critical review of needs and methods. Progress in food & nutrition science 1993;17(3):223–260. [PubMed: 8234779]
6. Chen Y, Cao Y, Allen V, Richards JS. Weight matters: physical and psychosocial well being of persons with spinal cord injury in relation to body mass index. Archives of physical medicine and rehabilitation 2011;92(3):391–398. [PubMed: 21238950]
7. Wu TY, Liaw CK, Chen FC, Kuo KL, Chie WC, Yang RS. Sarcopenia Screened With SARC-F Questionnaire Is Associated With Quality of Life and 4-Year Mortality. Journal of the American Medical Directors Association 2016;17(12):1129–1135. [PubMed: 27666334]
8. Xiao DY, Luo S, O'Brian K, et al. Impact of sarcopenia on treatment tolerance in United States veterans with diffuse large B-cell lymphoma treated with CHOP-based chemotherapy. American journal of hematology 2016;91(10):1002–1007. [PubMed: 27356783]
9. Kyle UG, Bosaeus I, De Lorenzo AD, et al. Bioelectrical impedance analysis--part I: review of principles and methods. Clinical nutrition (Edinburgh, Scotland) 2004;23(5):1226–1243.
10. Kyle UG, Bosaeus I, De Lorenzo AD, et al. Bioelectrical impedance analysis-part II: utilization in clinical practice. Clinical nutrition (Edinburgh, Scotland) 2004;23(6):1430–1453.
11. Duren DL, Sherwood RJ, Czerwinski SA, et al. Body Composition Methods: Comparisons and Interpretation. Journal of diabetes science and technology (Online) 2008;2(6):1139–1146.
12. Organ LW, Bradham GB, Gore DT, Lozier SL. Segmental bioelectrical impedance analysis: theory and application of a new technique. J Appl Physiol (1985) 1994;77(1):98–112. [PubMed: 7961281]
13. Ward CL, Suh Y, Lane AD, et al. Body composition and physical function in women with multiple sclerosis. Journal of rehabilitation research and development 2013;50(8):1139–1147. [PubMed: 24458900]
14. Ellis KJ. Human body composition: in vivo methods. Physiological reviews 2000;80(2):649–680. [PubMed: 10747204]
15. Fuller NJ, Laskey MA, Elia M. Assessment of the composition of major body regions by dual-energy X-ray absorptiometry (DEXA), with special reference to limb muscle mass. Clin Physiol 1992;12(3):253–266. [PubMed: 1606809]

16. Wang ZM, Visser M, Ma R, et al. Skeletal muscle mass: evaluation of neutron activation and dual-energy X-ray absorptiometry methods. *Journal of Applied Physiology* 1996;80(3):824–831. [PubMed: 8964743]
17. Haarbo J, Gotfredsen A, Hassager C, Christiansen C. Validation of body 312 composition by dual energy X-ray absorptiometry (DEXA). *Clin Physiol* 1991;11(4):331–341. [PubMed: 1914437]
18. Kaul S, Rothney MP, Peters DM, et al. Dual-energy X-ray absorptiometry for quantification of visceral fat. *Obesity (Silver Spring, Md.)* 2012;20(6):1313–1318.
19. Rothney MP, Martin FP, Xia Y, et al. Precision of GE Lunar iDXA for the measurement of total and regional body composition in nonobese adults. *Journal of clinical densitometry : the official journal of the International Society for Clinical Densitometry* 2012;15(4):399–404. [PubMed: 22542222]
20. Garrow JS, Webster J. Quetelet's index (W/H²) as a measure of fatness. *International journal of obesity* 1984;9(2):147–153.
21. Bosc-Westphal A, Schautz B, Later W, Kehayias JJ, Gallagher D, Muller MJ. What makes a BIA equation unique? Validity of eight-electrode multifrequency BIA to estimate body composition in a healthy adult population. *European journal of clinical nutrition* 2013;67 Suppl 1:S14–21. [PubMed: 23299866]
22. Rothney MP, Brychta RJ, Schaefer EV, Chen KY, Skarulis MC. Body composition measured by dual-energy X-ray absorptiometry half-body scans in obese adults. *Obesity (Silver Spring, Md.)* 2009;17(6):1281–1286.
23. IBM SPSS Statistics [computer program]. Version 23 Armonk, NY: IBM.
24. Cohen J Statistical Power Analysis for the Behavioral Sciences 2nd ed. Mahwah, NJ: 330 Lawrence Erlbaum Associates; 1988.
25. Johnson Stoklossa CA, Forhan M, Padwal RS, Gonzalez MC, Prado CM. Practical Considerations for Body Composition Assessment of Adults with Class II/III Obesity Using Bioelectrical Impedance Analysis or Dual-Energy X-Ray Absorptiometry. *Current obesity reports* 2016;5(4):389–396. [PubMed: 27591783]
26. Ortiz O, Russell M, Daley TL, et al. Differences in skeletal muscle and bone mineral mass between black and white females and their relevance to estimates of body composition. *The American journal of clinical nutrition* 1992;55(1):8–13. [PubMed: 1728823]
27. Carroll JF, Chiapa AL, Rodriguez M, et al. Visceral Fat, Waist Circumference, and BMI: Impact of Race/ethnicity. *Obesity* 2008;16(3):600–607. [PubMed: 18239557]
28. Jones A, Jr., Shen W, St-Onge MP, et al. Body-composition differences between African American and white women: relation to resting energy requirements. *The American journal of clinical nutrition* 2004;79(5):780–786. [PubMed: 15113715]
29. Demerath EW, Sun SS, Rogers N, et al. Anatomical Patterning of Visceral Adipose Tissue: Race, Sex, and Age Variation. *Obesity* 2007;15(12):2984–2993. [PubMed: 18198307]

Figure 1: Bland-Altman plots demonstrating relative agreement of lean mass (kg) predictions between Dual-Energy X-ray Absorptiometry (DXA) and segmental bioelectrical impedance (BIA). Segments shown are a) total body, b) arm, c) leg, and d) trunk.

Figure 2:

Bland-Altman plots demonstrating relative agreement of fat mass (kg) predictions between Dual-Energy X-ray Absorptiometry (DXA) and segmental bioelectrical impedance (BIA). Segments shown are a) total body, b) arm, c) leg, and d) trunk.

Figure 3:

Lean mass (kg) estimates for each pilot participant as measured by DXA (black bars) and segmental BIA (gray bars). Segments shown are a) whole body, b) trunk, c) arm and d) leg. Participants are ordered low to high by segment mass as measured by DXA.

Figure 4:

Fat mass (kg) estimates for each pilot participant as measured by DXA (black bars) and segmental BIA (gray bars). Segments shown are a) whole body, b) trunk, c) arm and d) leg. Participants are ordered low to high by segment mass as measured by DXA.

Table 1.

Characteristics of the study population

	Female (n= 16) Mean $\pm$ SD Range	Male (n= 14) Mean $\pm$ SD Range	All (n=30) Mean $\pm$ SD Range
Age, years	32.88 $\pm$ 13.99 (19–59)	30.71 $\pm$ 11.17 (19–61)	31.87 $\pm$ 12.59 (19–61)
Body mass, (kg)	74.81 $\pm$ 14.76 (51.43–99.86)	91.85 $\pm$ 26.61 (57.82–149.52)	82.76 $\pm$ 22.37 (51.43–149.52)
Height (cm)	167.88 $\pm$ 5.33 (154.50–172.90)	176.89 $\pm$ 7.24* (163.50–191.10)	172.08 $\pm$ 7.69 (154.50–191.10)
BMI (kg/m ²)	26.74 $\pm$ 5.44 (18.90–35.20)	29.02 $\pm$ 7.64 (21.00–46.57)	27.81 $\pm$ 6.60 (18.90–46.57)
Waist Circumference (cm)	87.19 $\pm$ 16.80 (68.00–113.50)	94.60 $\pm$ 19.16 (68.00–141.00)	90.65 $\pm$ 18.02 (68.00–141.00)

*
p<.05 for difference between sex

Table 2.

Total and segmental body composition estimates by DXA and BIA

	DXA Mean (SD)	BIA Mean (SD)	<i>p</i> value for Paired Sample t-test	Cohen's <i>d</i>	Pearson <i>r</i>
Total body					
Total mass, kg	82.56 (22.15)	81.58 (21.85)	.11	.31	.99**
Fat mass, kg	27.92 (13.36)	23.76 (11.17)	.14	.95	.95**
Lean mass, kg	51.77 (13.13)	54.89 (14.92)	<.001	1.17	.99**
Arm					
Total mass, kg	9.33 (2.99)	8.54 (2.79)	<.001	1.08	.97**
Right arm	4.70 (1.49)	3.76 (1.20)	<.001	2.15	.97**
Left arm	4.63 (1.51)	4.79 (1.60)	.05	.41	.97**
Fat mass, kg	3.01 (1.32)	2.59 (1.31)	<.001	.80	.92**
Right arm	1.51 (.65)	1.31 (.12)	<.001	.37	.92**
Left arm	1.50 (.67)	1.28 (.64)	<.001	.89	.93**
Lean mass, kg	5.93 (2.32)	6.91 (2.68)	<.001	1.24	.96**
Right arm	2.99 (1.16)	3.53 (1.34)	<.001	1.36	.96**
Left arm	2.94 (1.15)	3.38 (1.34)	<.001	1.10	.96**
Leg					
Total mass, kg	29.20 (7.42)	26.46 (6.49)	<.001	1.64	.98**
Right leg	14.71 (3.74)	13.22 (3.23)	<.001	1.73	.98**
Left leg	14.49 (3.68)	13.24 (3.25)	<.001	1.54	.98**
Fat mass, kg	9.46 (3.96)	7.52 (2.92)	.001	.96	.87**
Right leg	4.76 (2.01)	3.77 (1.47)	<.001	.96	.87**
Left leg	4.70 (1.95)	3.75 (1.45)	<.001	.93	.86**
Lean mass, kg	18.68 (5.33)	18.35 (5.48)	.19	.25	.97**
Right leg	9.41 (2.69)	9.14 (2.71)	.03	.41	.97**
Left leg	9.27 (2.64)	9.22 (2.78)	.70	.07	.97**
Trunk					
Total mass, kg	39.45 (11.85)	40.40 (12.12)	.09	.32	.97**
Fat mass, kg	14.57 (8.59)	14.35 (7.88)	.68	.08	.94**
Lean mass, kg	24.00 (5.38)	29.58 (6.89)	<.001	2.43	.96**