Original Research

Validation of Three Body Composition Techniques with a Comparison of Ultrasound Abdominal Fat Depths against an Octopolar Bioelectrical Impedance Device

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ABSTRACT

International Journal of Exercise Science 5(3) : 205-213, 2012. The aims of this study were to cross-validate three clinical-grade measures of body composition, using an octopolar Bioelectrical Impedance (BIA), an ultrasound analyzer (US) and Air-Displacement Plethysmography (ADP) and second to compare the US scans of total abdominal, subcutaneous and visceral fat depths (mm) against the trunk percent fat (%BF) from the octopolar BIA. Twenty-six college-aged (22.9 ± 1.35 years) men (n = 18) and women (n = 8) volunteered to participate in this study. Body composition was assessed using BIA (total and by segments), ADP and US. In addition, total abdominal, subcutaneous and visceral fat layers were measured using the US. All measurements were done in accordance with manufacturers' guidelines. The %BF comparing the three clinical grade machines were all significantly correlated and no significant differences were found using a 1-way ANOVA. All three fat depths were significantly correlated to the trunk fat % via BIA, while significant differences were found for the 1-way ANOVA. A Tukey post-hoc test showed significant differences between the BIA trunk %BF and both subcutaneous and visceral US fat depths. Having valid ways to measure body composition and visceral fat that is accessible in terms of being transportable, cost effective, and simple to use, should become a part of preventive medicine.

KEY WORDS: Body composition, visceral fat, subcutaneous fat

INTRODUCTION

Excess abdominal fat has shown to be strongly associated with increased risk for many obesity-related conditions including insulin resistance, type 2 diabetes, dyslipidemia, hypertension, the metabolic syndrome, and cardiovascular disease (3, 15). While the association is strong, researchers are reporting a number of cases of obesity that are not accompanied by metabolic disturbances (14, 21, 23), and at the other extreme genetic research is reporting normal or underweight subjects with metabolic abnormalities and increased risk (10). The conundrum may arise from the measurement method used. The most commonly reported tool, Body Mass Index

(BMI) is not a direct measure of body fat though the terms used to identify groups – overweight, obese and morbidly obese seem to suggest it is (14, 17).

Currently, the Center for Disease Control and Prevention (3) and the World Health Organization (25) use BMI to assess an individual's risk for hypokinetic diseases. Both associations have added waist circumference attempting to improve both the reliability and validity of analysis (3, 25). When the research included age groups the 20 and 55 year olds showed the greatest association for relative risk (22). The most current research showing variability in risk has used techniques that measured fat and identified locations that appear to be associated with the increased risk (10, 14, 19, 21, 23).Visceral fat especially around the liver has shown increased risk with and without high levels of subcutaneous fat (10, 14, 19, 21, 23), which helps support the idea that waist circumference is a good addition to the measurement of BMI to improve the validity of relative risk.

When used without the waist circumference, BMI has been found to incorrectly classify an individual due to gender fat distribution, athletic activities, and age (1, 5). In addition, as many as 20% to 30% of obese individuals are identified as having benign obesity (14, 23, 24) meaning they are truly overweight, have excess fat according to standards, but no additional risk. As obesity rates continue to climb, it is important to track not only BMI as a measure of risk, but also body composition to identify changes in fat mass, both amount and location, as weight changes (10, 14, 19, 21, 23). It may be necessary to identify ways to compliment BMI circumference with more sophisticated tools to correctly identify risk.

Currently, the public health messages focusing on the obesity epidemic have encouraged individuals to be interested in regular measurement of body composition. The cost of assessment can range from only a few dollars to thousands of dollars depending on the equipment used and the technical skills required for the test. Dual Energy X-Ray Absorptiometry (DEXA), Magnetic Resonance Imaging (MRI), Computed Tomography (CT) and research-grade Ultrasound (US) are the most accurate clinical methods used to measure body composition because they actually measure the density of the fat rather than just estimating the density as all other methods do (4, 19, 24). These methods are expensive and require technical skills to assure correct results. When used to measure body composition, these methods are primarily used for clinical research and are rarely available to the general public to measure body composition due to the accessibility and underlying cost (4, 19, 24).

Midrange priced assessments are either done with expensive equipment like the BodPod® using air displacement plethsmography (ADP) or hydrostatic weighing (HW), which have limited availability, or a technique requiring skill like skinfold assessment commonly used in fitness and wellness centers by certified fitness professionals. In the last fifteen years, a new method to assess percent body fat (%BF), bioelectrical impedance (BIA) devices, was developed. They can be found in a variety of locations from research settings to wellness centers to the home and because many are designed like a scale no technician is required for their use.

Early consumer-grade BIA machines measured specific segments either the arms via hand-to-hand devices or the legs via foot-to-foot scales. Research comparing these machines to a gold standard for body composition has demonstrated significant correlations, but not strong validity (7, 8, 17, 18). As research has identified visceral fat as having the greatest relative risk (3, 12, 13, 14, 15) BIA machines were developed that measure individual segments including the trunk. Even though these BIA machines can identify %BF in the abdomen or trunk, or you can measure an abdominal skinfold, none of the currently researched midrange clinical or consumer-grade devices were able to differentiate between subcutaneous and visceral fat in the abdomen. Even the more expensive methods like DEXA currently being used in large epidemiological studies cannot identify the difference (14). It must be assumed the trunk measure in all these assessments is a combination of subcutaneous and visceral fat.

Recently, a new ultrasound (US) device the Body Metrics BX-2000 manufactured by InteliMetrix was created to be a midrange clinical method used by fitness and wellness professionals. It not only measures %BF, but also has the capacity to identify and measure both subcutaneous and visceral fat layers independently. The device has not been validated against other commonly used instruments so the first aim of this study was to cross-validate three midrange clinical-grade measures of body composition using an octopolar BIA, the new US, and ADP. Because the literature suggests that just measuring body composition, while a better tool than just BMI to assess risk, it is still lacking unless it can identify visceral fat content. Therefore, the second purpose was to compare the US scans of total abdominal, subcutaneous and visceral fat depths (mm) against the trunk %BF from the octopolar BIA.

METHODS

Participants

Twenty-six college-aged (22.9 ± 1.35 years) men (n = 18) and women (n = 8) volunteered to participate in this study. Prior to recruitment, the Institutional Review Board for Human Subjects (IRB) at Eastern Washington University approved the study and all participants signed an informed consent prior to testing. All participants were provided written and verbal instructions 48 hours prior to testing and returned the signed informed consent the day of testing. Selection criterion required participants to complete a PAR-Q health history form with no answers marked ‘yes.’ Additionally, participants were required to be non-smokers, not pregnant, between the ages of 18 and 35, and free from any musculoskeletal or respiratory conditions.

Protocol

Participants were asked to abstain from eating or drinking for two hours as well as to refrain from moderate or vigorous exercise for 24 hours before all testing. They were told to obtain a restful night’s sleep, remain well hydrated, refrain from alcohol, and eat a regular meal in the morning before testing. When participants arrived at the Human Performance Lab for testing each verbally confirmed they followed all pre-testing requests. All testing was done with males wearing spandex shorts and no shirt, and females wearing a sports bra and spandex shorts. Anthropometric measurements of height and weight were taken using a beam scale (Dectecto Physician Scale, Cardinal Scale Manufacturing Co., Webb City, MO) with the subject barefoot. The order of testing was all participants completed the ADP first so the weight determined could be used for the US assessment. BIA and US were randomly assigned for the second and third tests.

Air-Displacement Plethysmography: The ADP was the first test conducted using the BodPod® (Life Measurement Instruments, Concord, California). Participants were required to wear a lycra swim cap during testing. All testing followed manufacturers' guidelines and if values given were declared invalid, the test was repeated. All participants had completed an ADP test previously but with an estimated residual lung volume (RV). None had completed the actual measure of RV so that portion of the test was explained and practiced prior to the assessment. They were taught the finger signals to follow when closed in the BodPod® and practiced the "puffs" required for the test. Procedures for estimating % BF were completed using the default Siri equation because no sport-specific formulas are included as options and no participants matched the criteria for alternate formulas available (children, African-American, extremely lean or obese). Following the general measure in the BodPod®, when the option to measure or estimate RV was given, the procedures to complete the RV measure were followed. The results were printed and the weight reported was used for the US measure.

Bioelectrical Impedance: Bioelectrical impendence was measured using the octopolar TANITA BC-418 MA® (Tanita Corporation of America, Inc., Arlington Heights, IL). The participant's age, gender, body type (selecting either athletic or standard based on their regular physical activity), and height were entered into the machine, and a standard 0.6 lbs (the lowest option possible) was entered as the adjustment for clothing weight for all participants. They stood barefoot on the metal footplate and held the handles with their arms relaxed by their side. Once impedance was measured, the results of Fat Mass (FM), Fat Free Mass (FFM), body water, and %BF for five different body locations, each arm, each leg, and the trunk and one general overall set was printed.

Ultrasound System: The US test was conducted via the BodyMetrics Pro System, (IntelaMetrix, Inc., Livermore, CA). Scans were done with the gelled wand placed at a 90-degree angle at the abdomen, chest/pectoralis, and thigh for males and thigh, triceps, and suprailliac for females. These locations are used in the prediction equations supplied by the manufacturer in their software. Care was taken to avoid compression of the subcutaneous fat as the wand was moved in a small circle (approximately 1 in) over the location to provide local averaging until the machine read the scan. After the scans were performed and confirmed as read, participants were then categorized depending on training history into standard, athletic, or elite fitness for the %BF determination. The manufacturer uses a proprietary formula to adjust the %BF from the general formula to fitness levels.

Next an abdominal scan was performed to determine total abdominal, subcutaneous, and visceral fat depths (mm). The wand was re-gelled before it was placed at a 90-degree angle one inch to the right side of the umbilicus. The abdominal scan was performed by slowly moving the device back and forth three to four inches towards the hip, making sure the device was held perpendicular to the skin and without compression throughout the scan. This scan is not used in a formula so the measurement depths had to be determined. In the measured US signal, the first strong reflection occurs at the fat-muscle interface which can be identified across the scan. The fat layers are not constant, so the depth can vary across the scan. Once the scan was recorded, two independent evaluators determined the greatest depth (mm) of the two fat layers combined, subcutaneous and visceral across the scan. The individual depths were recorded from that point when both technicians agreed. Total abdominal fat was recorded as the sum of the two fat layers.

Statistical Analysis

Descriptive statistics of mean ± SD were performed for all variables followed by two Pearson's correlations and two 1-way ANOVAs. The first assessment was to determine associations between the three body composition measures, and the second considered the associations between the three total fat depths (mm) against the trunk %BF reported from the octopolar BIA. Statistical analyses were performed using SPSS version 17.0 (SPSS Inc., Chicago, IL).

RESULTS

When reporting the %BF comparing the three clinical grade machines all were significantly correlated with high (> .85) r values (see table 1). This was despite slightly different formulas being used, i.e., the ADP was the standard Siri equation for general populations, while both the BIA and US used proprietary formulas with an assessment of activity to correct or select their formulas. No significant differences were found using a 1-way ANOVA.

Table 1. Pearson Product Moment Correlations between machines for %BF.

%BF by Machine (M ± SD)	BIA	US	ADP
BIA (15.3 ± 8.43)	1		
US (15.7 ± 5.14)	.862**	1	
ADP (15.5 ± 5.83)	.872**	.879**	1

** p = 0.01

BIA = Bioelectrical Impedance, US = Ultrasound, ADP = Air Displacement Plethsmography, %BF = Percent Body Fat.

For the second purpose, when comparing all three fat depths to the trunk %BF via BIA, all variables were significantly correlated (see Table 2). Even though the measures were significantly correlated for visceral fat to both BIA trunk %BF and US subcutaneous fat depth the r values are well below.70 which raises a question about the strength or magnitude of those significant relationships. Significant differences were found between groups in a 1-way ANOVA (F = 14.659, p = 0.001) therefore a Tukey post hoc test was also conducted. The BIA trunk %BF was significantly different from both the subcutaneous fat depth (p = 0.0001) and visceral fat depth (p = 0.004) but not for total fat depth.

Table 2. Pearson Product Moment Correlations of trunk %BF via BIA and US fat depths (mm).

Variables (M ± SD)	BIA Trunk %BF	US Subcutan-eous	US Visceral	US Total Abdominal
BIA Trunk %BF (17.9 ± 7.1)	1			
US Subcutaneous (9.25 ± 3.75)	.713**	1		
US Visceral (11.04 ± 6.94)	.540**	.473*	1	
US Total Abdominal (20.2 ± 9.32)	.689**	.755**	.935**	1

BIA = Bioelectrical Impedance, US = Ultrasound, %BF = Percent Body Fat. *p = 0.05, **p = 0.01

DISCUSSION

Having valid ways to measure body composition that is accessible in terms of being transportable, cost effective, and simple to use, should become a part of preventive medicine. Additionally, it is important for fitness providers to use valid measures of body composition regularly. Regular measurement will allow for better tracking of an individual's %BF both for prevention and treatment, help lower public health costs by identifying risk earlier, and help prevent certain pathologies (5, 18). In the present study, cross validation of the three clinical-grade devices, BIA, US, and ADP for %BF were all significantly correlated (p = 0.01), see Table 1. Percent body fat estimates with BIA versus ADP (r = 0.872) showed comparable correlations with those of Levenhagen et al., (r = 0.90) (11), and Biaggi et al., (r = 0.859) (2) both of which measured healthy adults.

Ultrasound machines used to determine %BF are relatively new so few validation studies have been reported. The only study found (18) used a higher grade ultrasound with better sonographic capabilities than the BodyMetrix Pro, but compared the US to the same equipment as the present study, ADP and BIA. In the study by Pineau et al., BF% correlations of ADP versus US (r = 0.91) and BIA versus US (r = 0.91) are consistent with the present results (r = 0.879) and (r = 0.862) respectively (18).

Since all three devices were significantly correlated in the present study the greatest advantage of this new BodyMetrix Pro US device compared to either ADP or BIA is it can also scan the abdomen and identify both the subcutaneous and visceral fat layers. Research consistently shows that visceral fat is associated with relative risk for a variety of metabolic diseases and the risk can be independent of BMI or overall body composition (10, 14, 19, 21, 23). Therefore, if all three are able to measure %BF with similar accuracy, the ability to measure visceral fat may be the deciding factor for which instrument to use with populations at risk for metabolic conditions (10, 14, 19, 21, 23).

Previous research has suggested that the use of an octopolar BIA device in various populations may be a better measurement of body composition, due to its ability to report %BF by segments; arms, legs, and trunk (9, 17). Our findings of total %BF via an octopolar BIA device are consistent with previous studies in healthy/obese children and adult populations (6, 18) for the measure of %BF. However, in studies where visceral fat measured by ultrasound was compared to the trunk measure of BIA no correlation was found (18, 20). In the present study, the US device, when compared to the BIA trunk measurement, was significantly correlated with all three measures; the subcutaneous fat (r = 0.713, p = 0.01), the visceral fat (r = 0.540, p = 0.01) and total abdominal fat depth (r = 0.689, p = 0.01). The r-value reported for the visceral fat, while significant, is low enough to question the magnitude of the correlation. While the correlation might be linear, individual differences in the visceral layer could have weakened the association.

The results of the 1-way ANOVA for the four measures lend strength to the question of the true significance of the correlation for visceral fat. The ANOVA was significant between groups so a Tukey post hoc test was conducted. When comparing the BIA %BF for the trunk to the three fat depth measures, only the total abdominal was not significantly different, so there is still debate about whether the BIA trunk measure is only truly associated with the total abdominal fat but not the visceral or subcutaneous layers by themselves.

Since other research is showing that BMI or percent fat alone may not be sensitive enough to identify those with unique risk factors (10, 14, 19, 21, 23), they suggest a measurement of visceral fat may provide a better assessment of risk. The population of the present study was relatively healthy college students while the populations in the other studies were identified as at risk for metabolic disease, so it is possible the significant correlation with the significant ANOVA for visceral fat is simply based on health and age.

Thus, if current health or fitness professionals were looking for ways to measure body composition, all three instruments used in this study can measure %BF with equal validity, the BIA adds the benefit of a trunk measure of %BF which may help identify risk, but only the US is able to measure visceral fat depth at the same time as it measures %BF. This study only used healthy college aged students, so the results found may be generalized to a young, relatively healthy population. Further research should include general and broader populations, i.e. obese children and adults as well as other individuals who present with risk factors for the lifestyle-related diseases such as insulin resistance, abdominal obesity, metabolic syndrome, or inflammation that are known to be associated with visceral fat.

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