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Validity of Various Bioelectrical Impedance Analysis Devices vs the Bod Pod for Body Composition

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VALIDITY OF VARIOUS BIOELECTRICAL IMPEDANCE ANALYSIS DEVICES VS THE BOD POD FOR BODY COMPOSITION

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ABSTRACT

Purpose: The purpose of this study was to determine the validity of various BIA devices compared to a criterion, the Bod Pod. It was hypothesized that (1) there would be no significant difference in the various BIA devices (Seca, Inbody, Tanita, Omron) as compared to the Bod Pod, for validity and reliability, (2) there would be no significant difference in total body water as measured by the Seca and Tanita, and (3) there would be significant differences in weight as measured by four of the five devices (Bod Pod, Seca, Tanita, Inbody). **Methods:** Forty participants, ages 18-31 years, 20 female and 20 males, were included in this study. Participants were tested on five devices (Bod Pod, Seca, Tanita, Omron, and Inbody), on the same day. A repeated measures ANOVA was used to assess device differences for percent fat and lean mass. For device differences, protected t-tests were used. Pearson correlations were used to assess predictive validity of each device vs the Bod Pod. **Results:** For percent fat, the Omron (20.5%) significantly ($p < 0.05$) underestimated percent fat as compared to all other devices: Bod Pod (24.1%), Seca (24.5%), Inbody (24.6%), Tanita (23.6%). The Omron also significantly ($p < 0.05$) overestimated lean mass as compared to all other devices. Reliability of each device was high (r^2 range = 0.995-1.000). There were no significant differences in total body water measured on the Seca (89.3 l) and the Tanita (90.0 l) BIA devices. For body weight, the Seca (73.5 kg) and the Inbody (73.7 kg) were significantly ($p < 0.05$) higher than the Bod Pod (73.4 kg) and the Tanita (73.4 kg). **Conclusion:** The Omron significantly

underestimated percent fat and overestimated lean body mass when compared to all other devices. The Seca, Inbody, and Tanita all showed acceptable validity as compared to the Bod Pod. However, the Omron is not recommended for body composition analysis.

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CHAPTER I

INTRODUCTION

Body composition is a topic of relevance for health professionals and health conscious individuals. Having excess body fat can lead to health risks including cardiovascular disease, hypertension, high cholesterol, diabetes and other diseases (Esmat, 2016). Having too little body fat can lead to malnutrition diseases that have the ability to become life threatening. Body composition methods vary greatly based on the types of information desired. Weight does not distinguish between fat and lean mass, so other methods are needed (Esmat, 2016).

Body composition measurements distinguish between fat and lean mass. Fat mass refers to the amount of fat that is not essential to the body, but serves as a nutritional reserve. Lean body mass includes essential fat found in bone marrow, heart, lungs, kidneys, liver, muscles, spleen, and intestines (McArdle, Katch & Katch, 2013).

Body composition can be measured both directly and indirectly. The direct method requires dissecting the body, which is only used with cadavers. Indirect methods include underwater weighing, air displacement plethysmography (Bod Pod), dual-energy x-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), and skinfolds

(McArdle et al., 2013). There are many different ways that body composition can be assessed, some more accurate than others. For the purposes of this study, the indirect methods of measurement included the Bod Pod which served as the criterion, versus the Tanita, Omron, InBody, and Seca BIA devices.

The Bod Pod utilizes air displacement plethysmography, based on pressure and volume changes to estimate body volume and density (Heymsfield, Lohman, Wang & Going, 2005). Volume and pressure are inversely related according to Boyle's Law, where one paired condition corresponds to the pressure and volume of the chamber when the Bod Pod is empty, and the other when the subject is sitting in the chamber (Heyward & Wagner, 2004). Boyle's Law does not assume that the air within the chamber is under adiabatic conditions, meaning the individual within the chamber gives off heat and air temperature is not constant (Heyward & Wagner, 2004). To account for this, the Bod Pod software uses Poisson's Law to represent a 40% difference between isothermic and adiabatic conditions (Heyward & Wagner, 2004).

Bioelectrical impedance analysis (BIA) uses a low-level electrical current that passes through the body, while impedance (opposition to flow) is measured (Heyward & Wagner, 2004). Total body water (TBW) can be estimated because greater than 75% of TBW is in the fat free mass, and electrolytes in TBW are conductors of the electrical current. When the volume of total body water is higher, the current is able to flow through the body easier and with less resistance compared to a lower volume of total body water (Heyward & Wagner, 2004). In individuals who have higher amounts of body fat, the flow of the current is less because adipose tissue is a poor electrical conductor (Heyward & Wagner, 2004).

BIA devices differ not only by affordability and accessibility, but also by their specific function. The Omron device measures upper-body impedance from electrodes via hand holds. The Tanita device measures lower-body impedance through electrodes via feet placement (Heyward & Wagner, 2004). The Inbody and Seca devices are similar in that they use a four-compartment method with electrodes via hand holds and feet placement. The four-compartment method estimates fat mass, total body water, and residual muscle mass from impedance in segmented measures.

Purpose

Many exercise science laboratories and wellness companies utilize different BIA devices to measure body composition, because they are inexpensive and easy to use. The purpose of this study was to determine the validity of various BIA devices (Seca, Inbody, Tanita, Omron) compared to a criterion, the Bod Pod, for body composition.

Hypotheses

The primary hypothesis of this study was that there would be no significant differences in the various BIA devices (Seca, Inbody, Tanita, Omron) as compared to the criterion, the Bod Pod, for percent fat and lean mass.

Secondary hypotheses included the following: 1. There would be no significant differences in weight as measured by four of the five devices (Bod Pod, Seca, Inbody, Tanita) which measure this variable. 2. There would be no significant differences in total body water as measured by the two devices (Seca, Tanita) which measure this variable. 3. All devices would be reliable based on no significant differences between two trials administered on each.

CHAPTER II

LITERATURE REVIEW

Parker, Reilly, Slater, Wells, & Pitsiladis (2003) assessed the validity of six popular field and laboratory methods for estimation of body fat. The methods of body composition used were the three-compartment method (fat mass, total body water, fat free mass) as a reference versus the Bod Pod, skinfolds, Tanita BIA, BodyStat BIA, and total body water (TBW) (Parker et al., 2003). The three-compartment method is based on measurements of body density and TBW, and controls for individual variation in fat free mass (FFM) hydration (Withers et al., 1998). This study focused on boys, ages 10-14 years, where mean body fat was 16.4 ± 11.6%. The results showed that the validity of the various measurements (three-compartment versus the Bod Pod, skinfolds, Tanita, Body Stat, and TBW) was poor (Parker et al., 2003). The results showed that only the three-compartment model versus TBW had high accuracy (Parker et al., 2003).

The Inbody 230 and Tanita Bc-418 BIA devices were compared against DXA for validity in 150 boys and girls, ages 7-12 years (Lee et al., 2017). Both the Inbody and the Tanita BIA devices underestimated DXA results for body fat percentage; the Tanita by

8.8% in boys and 9.7% in girls; the InBody by 3.0% in boys and 4.5% in girls (Lee et al., 2017).

The Inbody 720 and OMRON 306 BIA devices were compared by Finn, Saint-Maurice, Karsai, Ihász, & Csányi (2015) in 267 children and adolescents (145 males, 122 females, ages 10.4-17.9 years) tested on each device during a single session. The Omron device measured a significantly higher body fat percentage than the InBody device for both boys and girls. For boys, average body fat percentage on the InBody was 15.9% versus 20.6% for the Omron device; for girls, average body fat percentage on the InBody was 23.5% versus 25.4% on the Omron (Finn et al., 2015). Results of this study showed that estimates of body fat percentage were significantly higher on the Omron device than the Inbody (Finn et al., 2015).

The Bod Pod and DXA devices were compared by Jackson, Donaghy, Djafarian, & Reilly (2014) in 89 young children, 42 boys and 47 girls (mean age 4.1 $\pm$ 1.3 years). The study found that using total body water (TBW) as the reference method, there were no significant differences for the Bod Pod or DXA. Percent fat for the Bod Pod in boys was 21.9 $\pm$ 10.3%, and 26.6 $\pm$ 10.4% in girls. For the DEXA, percent fat in boys was 26.5 $\pm$ 6.1% and 30.5 $\pm$ 7.1% in girls (Jackson et al., 2014). On the other hand, the study found a significant difference between skinfold and TBW estimates of percent fat. Skinfold percent fat in the boys was 18.4 $\pm$ 5.7%, and 21.1 $\pm$ 6.9% in girls. TBW percent fat in boys was 25.3 $\pm$ 5.9%, and 27.7 $\pm$ 6.1% in girls. Jackson et al. (2014) found that the methods that were used within this study had low validity.

Dolezal, Lau, Abrazado, Storer, & Cooper (2013) validated body fat percentage measured by the Biospace InBody R20 and the Tanita BC-590BT BIA devices versus

DXA (Hologic 4500). Twenty-one subjects participated in this study (15 males, 6 females, age 37.6 ± 16.8 years) who were measured on each of the devices. Dolezal et al. (2013) found no significant differences between the BIA devices when compared to DXA. The percent fat mean of the Tanita was 23.5 ± 11.6%, Inbody was 25.5 ± 10.3%, and 25.3 ± 9.6% for the DEXA. Dolezal et al. (2013) suggested that the percent fat may have differed between devices due to hydration levels and the electrical conduction of the devices. This study was delimited to overweight subjects which may have impacted the results (Dolezal et al., 2013).

Kuriyan, Thomas, Ashok, Jayakumar, & Kurpad (2014) validated body fat estimates from the Bod Pod, DXA, skinfolds, and BIA (Quadscan 4000) methods against the four-compartment model. Thirty-nine healthy Indian subjects, 19 males, 20 females, ages 20-40 years, were measured by each of the devices. Kuriyan et al. (2014) found that the methods all underestimated body fat when compared to the four-compartment reference model (TBW, bone mineral, nonbone mineral, protein) except for DXA. The four-compartment method is typically more valid than the three-compartment method because it controls for variability in bone mineral and TBW (Withers et al., 1998). The mean fat mass from the four-compartment reference model was 17.6 ± 5.6 kg. The mean difference for DXA was -0.5 ± 1.6; Bod Pod was 0.6 ± 1.5; BIA was 3.4 ± 2.7; and skinfolds, 4.6 ± 2.4 kg (Kuriyan et al., 2014).

Bosy-Westphal et al. (2003) validated the Bod Pod against DXA in order to compare to a four-compartment model in the elderly. Twenty-six healthy, elderly subjects, 15 females, 11 males, ages 60-82 years, participated in the study. Bosy-Westphal et al. (2003) found that fat percentage with the Bod Pod was 1.6 ± 3.1% higher than by DXA, and 1.0 ± 2.8% higher than by the four-compartment model. The difference between the Bod Pod and DXA fat percentage was significant in both males and females, while the difference in the Bod Pod and the four-compartment model fat mass percentage was only significant in females (Bosy-Westphal et al., 2003). The authors concluded that the Bod Pod is a valid method in the elderly when compared to DXA ($r^2 = 0.87$) and the four-compartment model ($r^2 = 0.92$). It was concluded that differences in measurements could have been related to the water content of the fat free mass (Bosy-Westphal et al., 2003).

Gartner, Dioum, Delpeuch, Maire, & Schutz (2004) validated a hand-held BIA device (Omron HBF300) versus the Bod Pod for lean body mass and percentage body fat in 146 African women (mean age 31.0 ± 9.1 years). This study found that the Omron device overestimated lean body mass by 5.6 ± 2.6 kg and underestimated body fat percentage by 8.8 ± 3.7%, as compared to the Bod Pod (Gartner et al., 2004). Even with these differences, it was concluded that in African women, the use of the hand-held Omron was a valid ($r^2 = 0.83$) measurement tool in the field (Gartner et al., 2004).

Radley, Gately, Cooke, Carroll, Oldroyd, & Truscott (2003) assessed accuracy of body fat percentage estimates from the Bod Pod against DXA. Twenty-eight adolescents, 12 males, 16 females (mean age 14.9 ± 0.5 years), were tested on both DXA and the Bod Pod during a single testing session. The average percent fat for the Bod Pod using the Siri equation was 23.7 ± 9.1%, which was not significantly different from DXA (24.2 ± 10.2%) (Radley et al., 2004). However, the results for the Bod Pod with the Lohman equation (21.9 ± 9.2%) was significantly less than DXA (24.2 ± 10.2%). In males, percent fat by the Siri equation with the Bod Pod (18.7 ± 11.2%) was slightly greater than

DXA (18.1 ± 10.9%), while the Lohman equation (17.2 ± 11.4%) underestimated body fat percentage versus DXA (18.1 ± 10.9%) (Radley et al., 2004). In females, both the percent fat from the Siri equation (27.5 ± 4.8%) and the Lohman equation (25.5 ± 4.8%) were both underestimated when compared to DXA (28.8 ± 6.9%). The authors concluded that Bod Pod percent fat estimates were accurate in adolescent subjects (Radley et al., 2004).

Ginde et al. (2005) validated body density by the Bod Pod versus underwater weighing (UWW) in 123 (89 males, 34 females, mean age 46.5 ± 16.9 years) normal weight to obese individuals. Fifteen of the subjects were overweight (BMI 25-29.9 kg/m^2), 70 subjects were obese (30-39.9 kg/m^2), and 10 were severely obese (BMI ≥ 40 kg/m^2). The results showed no significant differences between UWW and the Bod Pod. Differences in body density between devices were: normal weight (0.002 ± 0.008 kg/L), overweight (0.004 ± 0.007 kg/L), obese (-0.001 ± 0.007 kg/L), and severely obese (0.001 ± 0.007 kg/L). Results showed that estimates of percent fat from UWW and the Bod Pod were correlated (r = 0.94). These results suggest that for body density in overweight and obese subjects, the Bod Pod is a valid tool for measurement (Ginde et al., 2005).

Lazzer, Bedogni, Agosti, De Col, Mornati, & Sartorio (2008) compared DXA, Bod Pod, and BIA in 58 severely obese (BMI 34.4 ± 4.9 kg/m^2) children and adolescents (27 males, 31 females; ages 10-17 years). Additionally, an external group of 61 obese (BMI 30.4 ± 4.2 kg/m^2) children and adolescents (mean age 14.0 ± 1.4 years) were used to validate the new equation developed in the study (Lazzer et al., 2008). When compared to DXA, the Bod Pod significantly underestimated percent fat but with acceptable error by 2.1% (± 3.4) in the whole group. In the boys, there was no significant difference (-1.2 ± 3.8%), but there was a significant underestimation in the girls (-2.9 ± 2.9%). The BIA device also underestimated percent fat in the whole group by 5.8% (± 4.6); boys by 6.1% (± 4.2); girls by 5.6% (± 4.2). The results suggested that the assessment of body composition by the Bod Pod and BIA may not be valid in this population (Lazzer et al., 2008).

Peterson, Repovich, & Parascand (2011) compared the accuracy of percent body fat from various BIA devices and skinfold formulas against the Bod Pod in 82 females (ages 19-67 years). Results showed significant relationships between the Bod Pod and skinfolds (r = 0.862), and all BIA devices: tetrapolar BIA (r = 0.553), finger to finger (r = 0.775), hand to hand (r = 0.771), leg to leg (1) (r = 0.765), leg to leg (2) (r = 0.791), leg to leg (3, athletic) (r = 0.798) and leg to leg (3, non-athletic) (r = 0.796) BIA devices. Mean percent fat differences vs the Bod Pod were not significant for skinfolds (1.9 ± 4.3%) or all BIA devices: tetrapolar BIA (0.7 ± 7.3%), finger to finger (-1.6 ± 5.3%), hand to hand (1.4 ± 5.4%), leg to leg (1) (4.7 ± 5.4%), leg to leg (2) (-3.7 ± 5.1%), leg to leg (3, athletic) (1.7 ± 5.1%), and leg to leg (3, non-athletic) (-6.1 ± 31.40%). The results of this study suggested that skinfold measurements were the most valid field method of body composition measurement (Peterson et al., 2011). For the BIA devices, the leg-to-leg (2) BIA device was the most valid while being the most cost-effective (Peterson et al., 2011).

Bailey, LeCheminant, Hope, Bell, & Tucker (2018) compared the InBody 720, GE iDXA, and the Bod Pod in 43 males and 37 females (mean age 31.4 ± 10.7 years). Assessments were performed over two days, where the participants were measured on each device twice on the first day, and once two days later. Results showed the strongest correlation between the GE iDXA and the Bod Pod (r = 0.98), followed by the InBody and the GE iDXA (r = 0.95), and the InBody and the Bod Pod (r = 0.93) (Bailey et al., 2018). Mean differences in body fat percentages were 1.8 $\pm$ 2.2% between the GE iDXA and the Bod Pod, 6.2 $\pm$ 3.4% between the GE iDXA and the InBody, and 4.4 $\pm$ 4.1 between the Bod Pod and the InBody. The results suggest that the InBody underestimated percent fat, while the Bod Pod and GE iDXA were within acceptable limits.

Bosy-Westphal et al., (2017) compared BIA against DXA and MRI in 123 multiethnic, healthy adults, 61 males, 62 females, ages 18-65 years. Ethnicities were 32 Caucasians, 31 Asians, 30 African-Americans, and 30 Hispanics. Subjects were tested on the Seca (8-electrodes), DXA, and MRI in order to validate a previously generated equation for skeletal muscle mass (SMM), visceral adipose tissue (VAT), and lean soft tissue (LST) (Bosy-Westphal et al., 2017). The study showed that Asians had lower SMM of the total body, legs, and arms when compared to Caucasians, while Hispanics had lower SMM of the legs when compared to African-Americans (Bosy-Westphal et al., 2017). When compared to Caucasians, Hispanics had a higher VAT while African-Americans had a lower VAT. When compared to African-Americans, Hispanics were the lowest for arm LST, followed by Asians, and Caucasians. Results of this study found that when compared to DXA, BIA equations based on MRI may be more accurate in the prediction of muscle mass (Bosy-Westphal et al., 2017).

Bosy-Westphal et al. (2013) validated an eight-electrode BIA device (Seca) to estimate body composition in 124 subjects (62 males, 62 females), ages 18-65 years. The study was conducted in two phases: the first phase was to develop a BIA equation to predict fat free mass (FFM), extra-cellular water (ECW), and total body water (TBW) using a four-compartment model. The second phase was to validate the equation that was created on 130 multiethnic, men and women, ages 18-65 years (Bosy-Westphal et al., 2013). Subjects were tested on the SECA, Bod Pod, and DXA in order to develop the equations. During the first phase, results showed poor validity in five cases while using the four-compartment model. Invalid data occurred three times for measurement of ECW, four times for measurement of TBW, and once for the measurement of total body volume via the Bod Pod. The second phase showed poor validity for the four-compartment results in 12 cases. Invalid data occurred two times for measurement of ECW, six times for measurement of TBW, and six times for measurement of total body volume using the Bod Pod (Bosy-Westphal et al., 2013). The authors concluded that the eight-electrode BIA method (SECA) is a valid tool when compared to the Bod Pod (Bosy-Westphal et al., 2013).

The studies reviewed above suggest that the Bod Pod may be the best tool when estimating percent body fat when compared to various BIA devices. Some BIA devices, such as the Seca, may be valid when compared to the Bod Pod. When comparing the various BIA devices against each other, the Omron device resulted in a higher body fat percentage than the Inbody for children, but in African American adults, the Omron underestimated percent fat compared to the Bod Pod. The Inbody and Tanita also underestimated body fat percentage when compared to DXA. Contradictory results may be due to differences in age (children, adults, elderly) and race of the studies reviewed.

CHAPTER III

METHODS

Research Design

The study used an experimental design where the independent variable was the device type (Bod Pod; Seca, Tanita, Omron, and In-body BIA devices). The dependent variable was body composition (percent fat and lean mass).

Each subject was tested on each device, on the same day, in a random order. The testing was all completed in the Human Performance Laboratory at Cleveland State University (CSU). Each subject was tested in the morning, after an overnight fast. The study was approved by the CSU Institutional Review Board (Appendix A) and all subjects signed an Informed Consent form (Appendix B) prior to participation.

Subjects

Flyers (Appendix C) were posted at the recreation center at CSU, and throughout buildings on the CSU campus. Subjects were also obtained through "word of mouth." A total of 40 subjects (20 males, 20 females) were obtained, ages ranging from 18 to 35 years. The subjects were of different ethnicities and general fitness levels. Exclusions for participation included those with pacemakers or prosthetic devices, pregnant women, or those with chronic or acute illness, as determined by questionnaire (Appendix D). There were no limitations regarding general fitness level or body fat percentage.

Procedures

Subjects were assigned to a random testing order for the Bod Pod, Seca, Tanita, Omron, and In-body BIA devices (Appendix E). They were informed to wear tight fitting clothing (i.e. compression shorts, sports bra for females), no jewelry, and to be normally hydrated, but fasted, for at least four hours prior to the testing. Before testing, each device was calibrated in order to ensure validity. Prior to all measures, height was measured by a stadiometer and weight by a physician's balance scale.

Before entering the Bod Pod, subjects were required to place a swim cap over their hair, and name, date of birth, gender, height, and ethnicity were entered into the computer. The Siri density model and predicted thoracic gas volume models were selected. The Bod Pod was calibrated by placing the calibration cylinder inside the Bod Pod, the door was closed, and the directions were followed on the screen. The subjects were then prompted to sit inside the Bod Pod and breathe normally for the first measurement. Once the first measurement was completed, the door was opened, and then closed again to begin the second measurement. If a third measurement was needed, the same procedures were followed. Once all measurements were completed, the results were displayed on the screen and a printout was obtained of all results (Cosmed, n.d.).

For the Seca device, name, date of birth, gender, ethnicity and an ID number were entered into the computer. The subject cleaned their feet on a towel, then stepped onto the device with bare feet to have their weight measured, and height was entered into the device (Seca, n.d.). The subject then placed their hands on the hand holds and stood still until the measurement was completed. Once all measurements were complete, a printout was obtained of all results. The same testing procedures were repeated a second time for reliability, with the mean used.

Before using the InBody device, the subjects cleaned their feet on a towel then stepped onto the device in order to obtain their weight. After weight was measured, height, age, and gender were entered into the device. The subject was then instructed to grasp the handles, holding their thumbs on the electrodes, and their arms straight and out to the side, not touching their body (InBody, n.d.). The subjects were instructed to stand still while the device obtained their measurements. Once the measurements were completed, a printout was obtained from the device. The same testing procedures were repeated a second time for reliability, with the mean used.

For the Tanita device, gender, age, height, and estimated weight of clothing was entered into the device (0.6 pounds, the lowest weight choice, was used for clothing). “Athletic mode” was selected as it has been found to be more accurate in this laboratory. Once all data was entered, the device prompted the subject to step onto the sensors. The subject wiped their feet on a towel prior to stepping on the device. Once the subject stood on the sensors, the device obtained the measurements. The subject was then instructed to step off the device while a printout of the results was obtained. The same testing procedures were repeated a second time for reliability, with the mean used.

For the Omron device, height, weight, age, gender, and either athlete or general population were entered into the device. When the data was entered, the screen on the device flashed “ready” to signal the subject to begin the test. The subjects were told to stand with their feet slightly apart and to grip the electrodes with their middle finger within the groove. The subjects then fully extended their arms in front of their body so they were at a 90-degree angle (Omron, n.d.). Once the subject was in position, the researcher pressed “start” to begin the test. Once the measure was completed, the researcher copied the results onto a data sheet. The same testing procedures were repeated a second time for reliability, with the mean used. All data was recorded on a data sheet (Appendix F).

Data Analysis

Descriptive statistics were obtained. Inferential statistics (repeated measures ANOVA) were used to compare all devices for percent fat and lean mass. For device differences, protected t-tests were used. Pearson correlations were used to assess predictive validity of each device vs the Bod Pod. SPSS (version 22) was used for all analyses. .05 was used as the level of significance for the ANOVA and Pearson correlations; .01 was used for the protected t-tests.

CHAPTER IV

RESULTS

A total of 40 subjects (20 males, 20 females) participated in the study to determine the validity of the various BIA devices compared to the criterion, the Bod Pod. Three of the subjects were Asian, one was African American, and 36 were Caucasians. Subject characteristics are shown in Table 1.

Table 1. Subject Characteristics.

	Total Sample (N=40)	Male (N=20)	Female (N=20)
Age (years)	23.1	23.4	22.9
Height (cm)	172.2	178.2	166.2
Weight (kg)	73.5	81.8	65.1

Percent Fat

Percent fat for each device is shown in Table 2. The Omron device averaged the lowest, while the Inbody averaged the highest percent fat. The Omron significantly ($p < .05$) underestimated percent fat compared to all other devices.

Table 2. Mean body fat percent for each device (N = 40).

	Mean	Std. Deviation	P-Values vs Bod Pod
BodPod	24.1	10.7	
Seca	24.5	9.1	.420
Tanita	23.6	8.0	.580
Omron *	20.5	7.4	.0001
Inbody	24.6	9.9	.285

*Omron significantly different from all others ($p < .05$).

Figures 1-4 show the predictive validity of each BIA device vs the criterion, the Bod Pod, for percent fat. The r^2 values were 0.907, 0.778, 0.854, and 0.917 respectively for the Seca, Tanita, Omron, and Inbody. The Seca and Inbody had the highest validity, but the Tanita and Omron were acceptable.

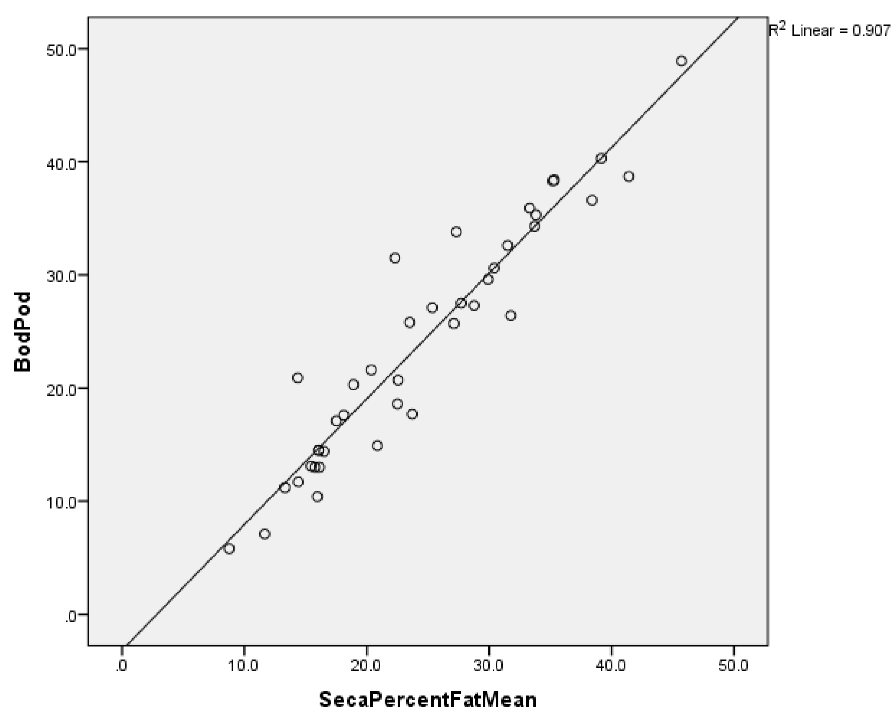

Figure 1. Relationship of the Seca to the Bod Pod for percent fat ($p = 0.420$).

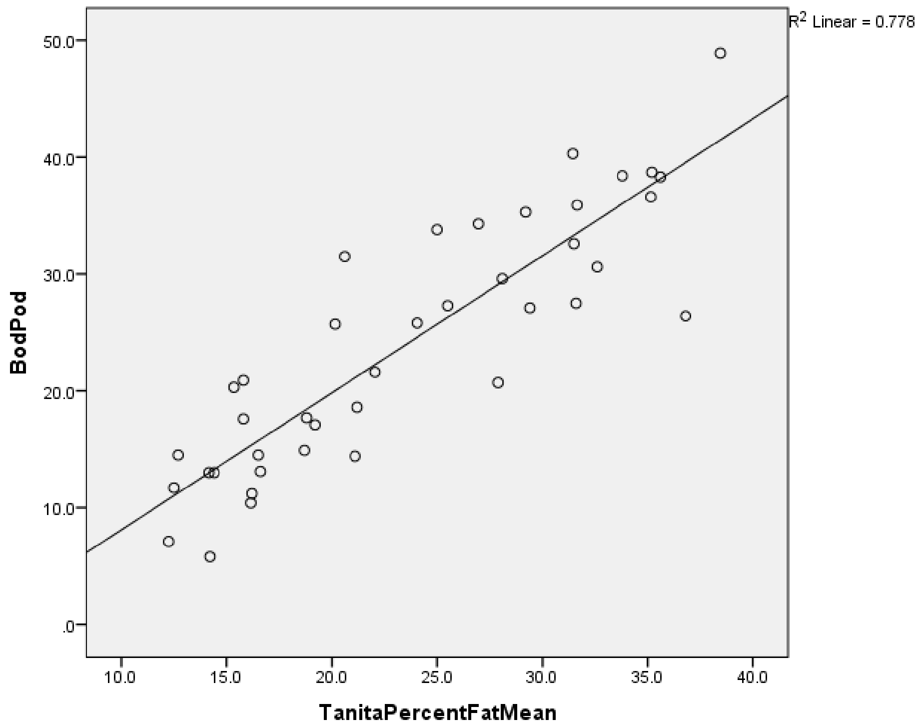

Figure 2. Relationship of the Tanita to the Bod Pod for percent fat ($p = 0.580$).

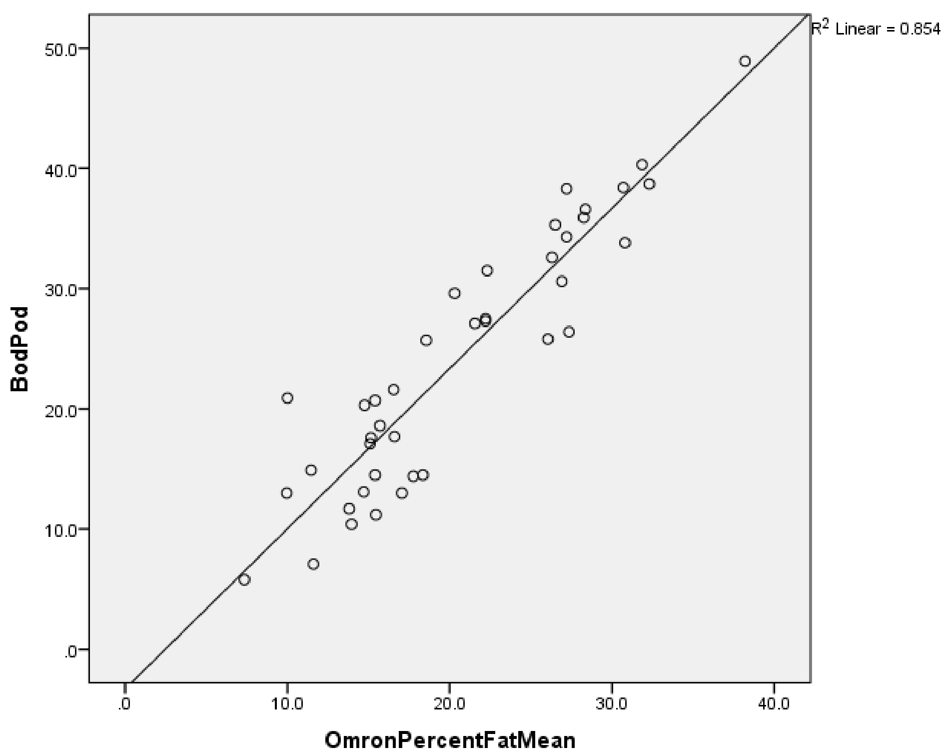

Figure 3. Relationship of the Omron to the Bod Pod for percent fat ($p = 0.0001$).

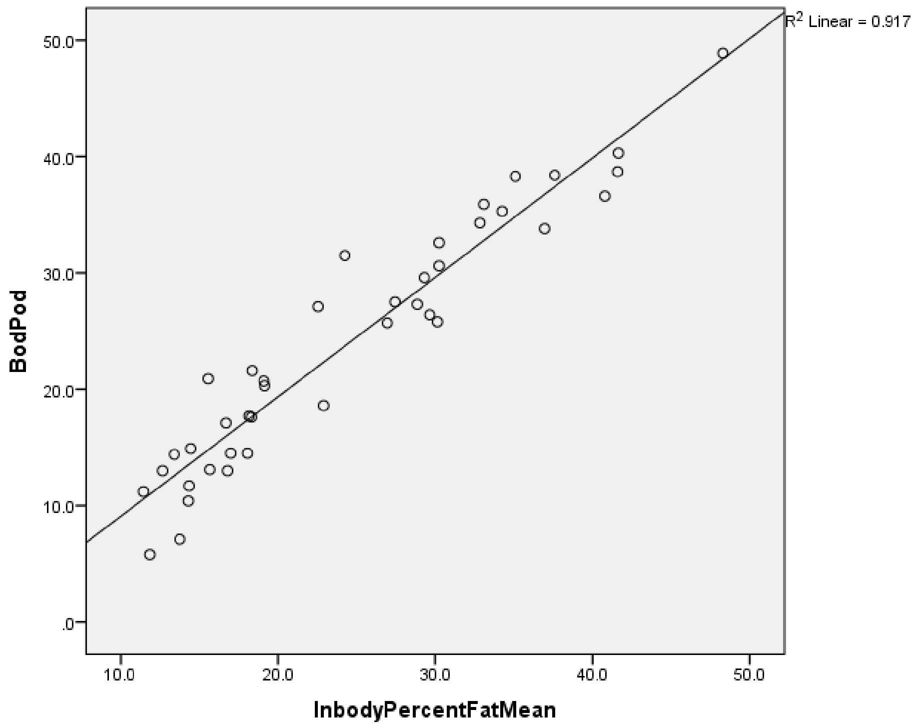

Figure 4. Relationship of the Inbody to the Bod Pod for percent fat (p = 0.285).

Lean Body Mass

Table 3 shows lean body mass for each device. The Omron averaged the highest, while the Inbody averaged the lowest mean lean body mass. The Omron significantly ($p < .05$) overestimated lean mass compared to all other devices.

Table 3. Mean lean body mass (kg) for each device (N = 40).

	Mean	Std. Deviation	P-values vs Bod Pod
BodPod	75.9	10.7	
Seca	75.5	9.1	.420
Tanita	76.4	8.0	.580
Omron *	79.5	7.4	.0001
Inbody	75.4	9.9	.285

*Omron significantly different from all others ($p < .05$).

Figures 5-8 show the predictive validity of each BIA device vs the criterion, the Bod Pod, for lean body mass. The r^2 values were 0.907, 0.778, 0.854, and 0.917 respectively, for the Seca, Tanita, Omron, and Inbody. The Seca and Inbody had the highest predictive validity, but the Tanita and Omron were acceptable.

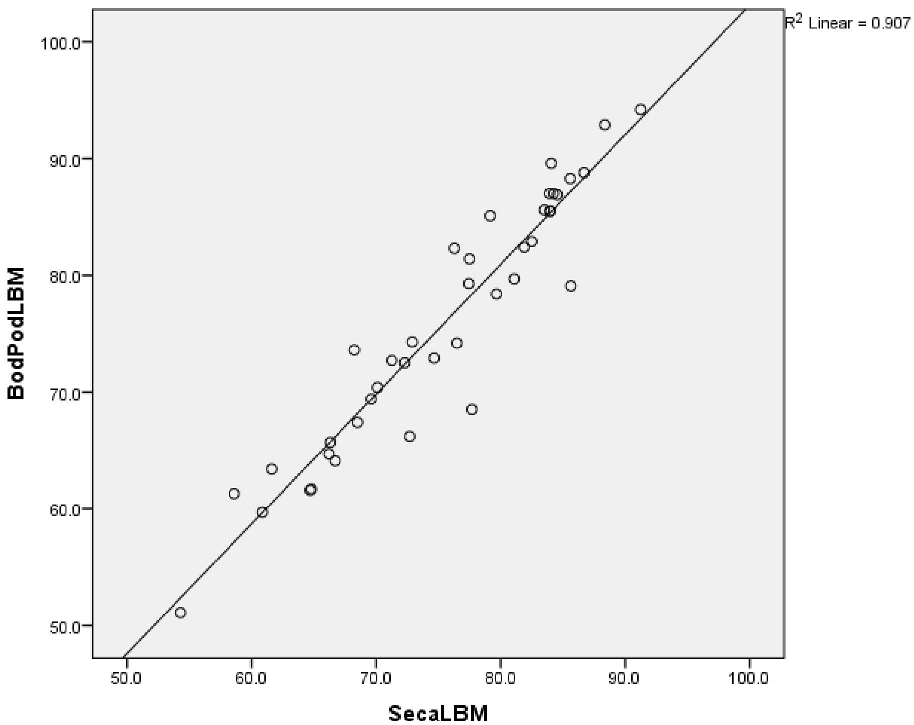

Figure 5. Relationship of the Seca to the Bod Pod for lean body mass (kg) (p = 0.420).

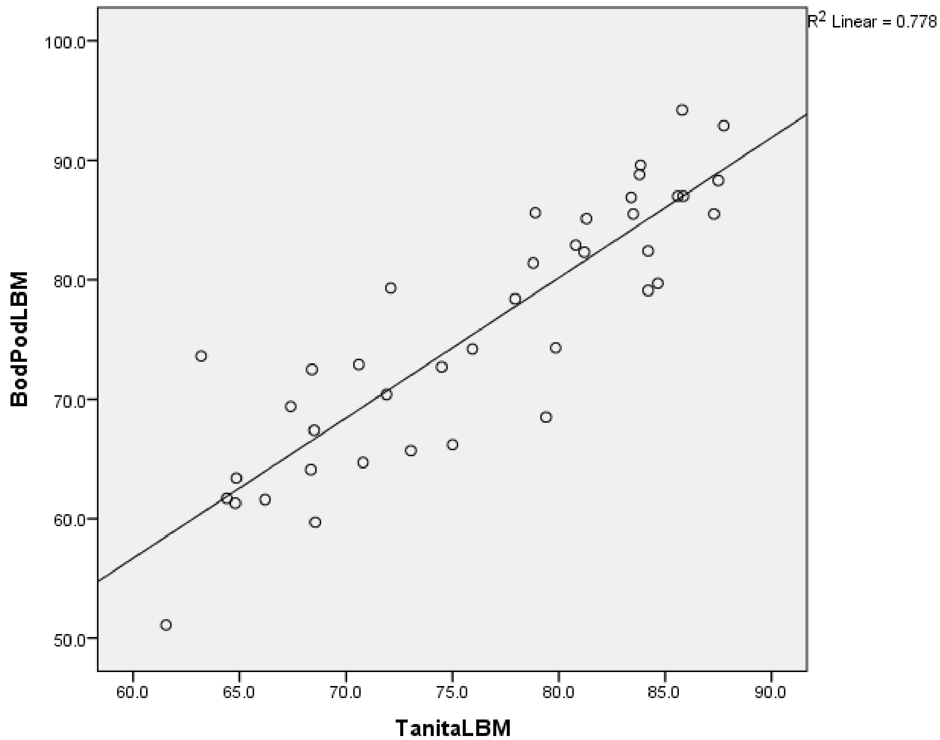

Figure 6. Relationship of the Tanita to the Bod Pod for lean body mass (kg) (p = 0.580).

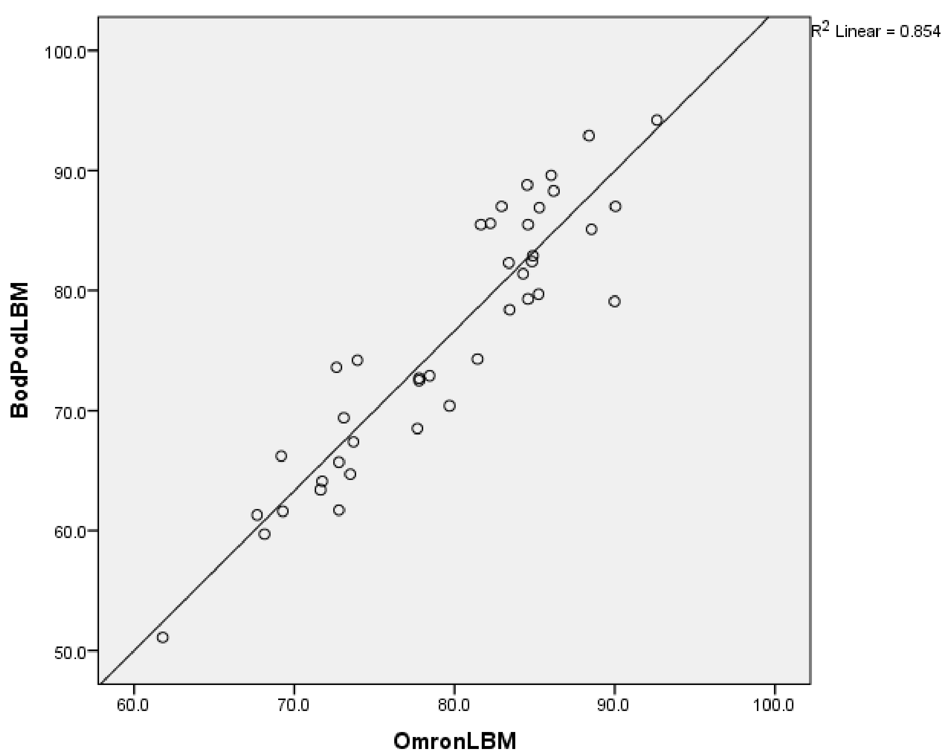

Figure 7. Relationship of the Omron to the Bod Pod for lean body mass (kg) (p =0.0001).

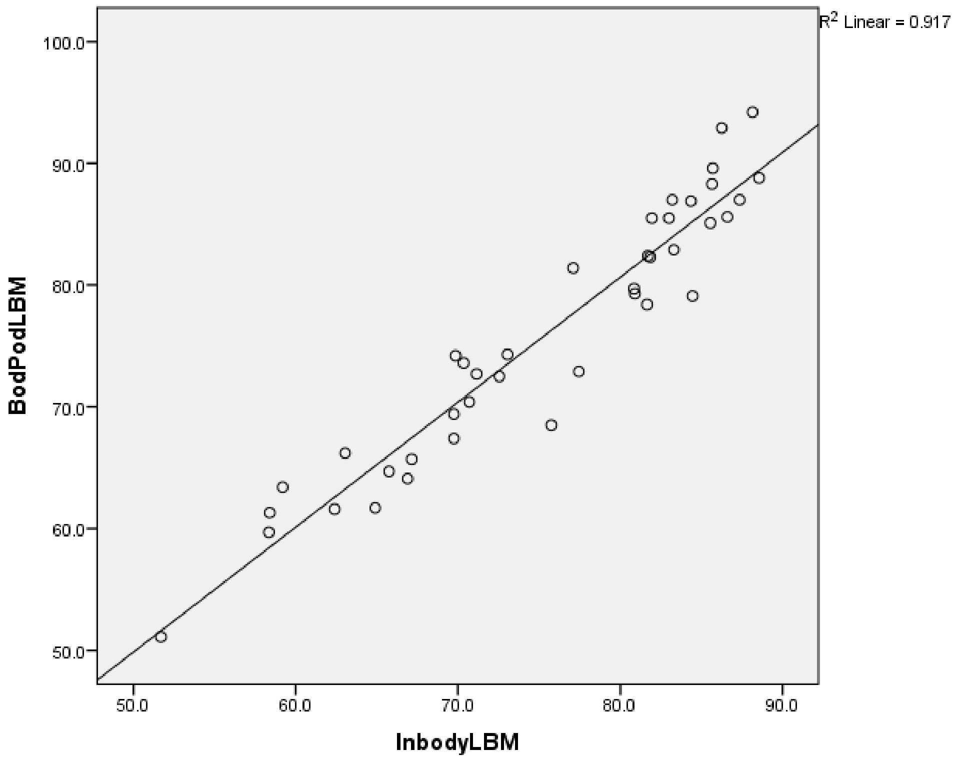

Figure 8. Relationship of the Inbody to the Bod Pod for lean body mass (kg) ($p = 0.285$).

Body Weight

Table 4 shows body weight (kg) for each device except the Omron, which does not measure weight. The Tanita averaged the lowest, while the Inbody averaged the highest mean body weight (kg). The Seca and Inbody were significantly ($p < .05$) higher than the Bod Pod and Tanita. It should be noted that the Tanita requires an estimated clothing weight. The lowest choice was used (0.6lbs).

Table 4. Mean body weight (kg) measured on four of the five devices (N = 40).

	Mean	Std. Deviation	P-values vs Bod Pod
BodPod	73.4	14.1	
Seca *	73.5	14.1	.0001
Tanita	73.4	14.1	.201
Inbody *	73.7	14.1	.0001

*Seca and Inbody significantly different from the Bod Pod and Tanita ($p < .05$).

Total Body Water

Table 5 shows total body water (l) for the Seca and Tanita, the only devices which measure this variable. Total body water was higher on the Tanita vs the Seca. However, this difference was not significant.

Table 5. Mean total body water (l) measured on the Seca and Tanita BIA devices (N = 40).

	Mean	Std. Deviation	P-values
Seca	89.3	20.4	
Tanita	90.0	19.9	.319

Figure 9 shows the relationship of total body water for the Seca vs Tanita. The r^2 value was 0.954, which was high.

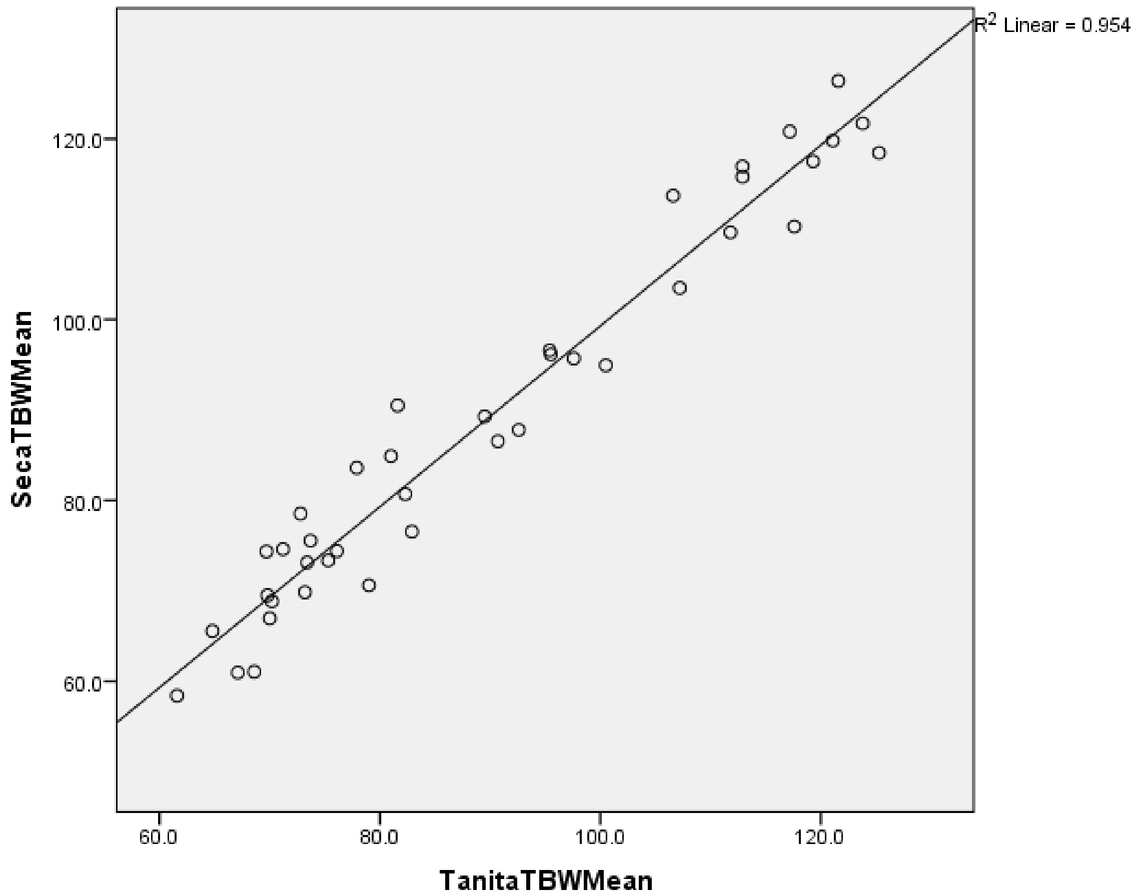

Figure 9. Relationship of Seca vs Tanita for total body water (p = 0.319).

Reliability

Table 6 shows the reliability of each BIA device for percent fat based on two trials. There were no significant differences.

Table 6. Reliability of percent fat for trial 1 vs trial 2 on each BIA device (N = 40).

	Mean	Std. Deviation	P-values
Seca Trial 1 Seca Trial 2	24.5 24.5	9.1 9.1	.508
Tanita Trial 1 Tanita Trial 2	23.8 23.5	8.1 8.0	.265
Omron Trial 1 Omron Trial 2	20.5 20.5	7.3 7.4	.720
Inbody Trial 1 Inbody Trial 2	24.5 24.6	9.9 10.0	.376

Figures 10-13 illustrate the reliability of each BIA device for percent fat based on two trials. The r^2 values were 0.998, 1.000, 0.995, and 0.996 respectively, for the Seca, Tanita, Omron, and Inbody. The reliability of each device for percent fat was high.

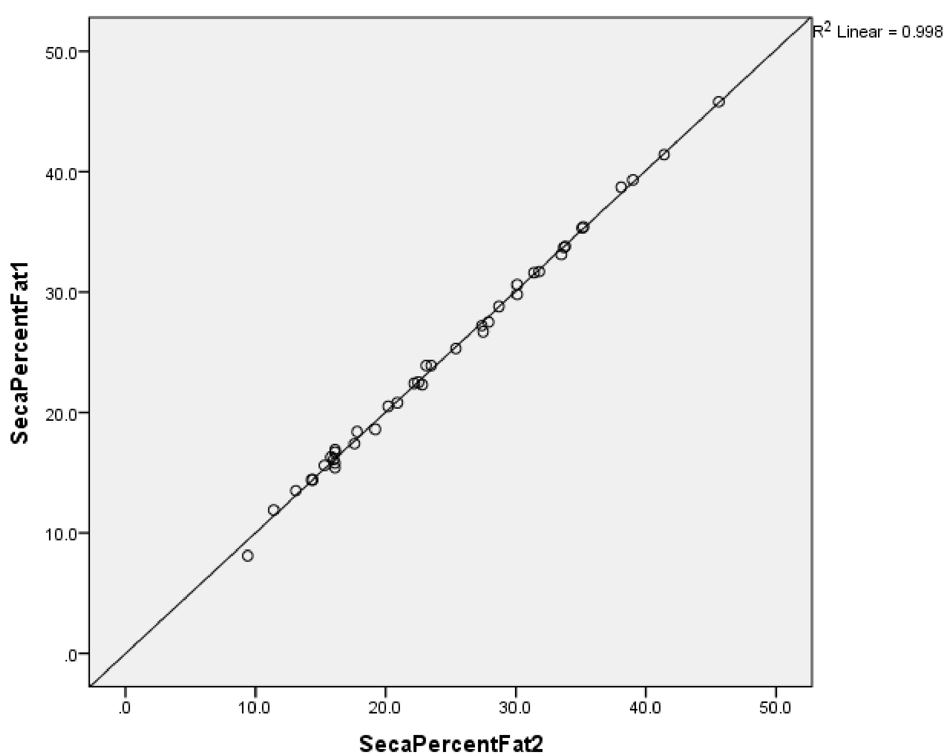

Figure 10. Relationship of trial 1 vs trial 2 of the Seca for percent fat (p = 0.508).

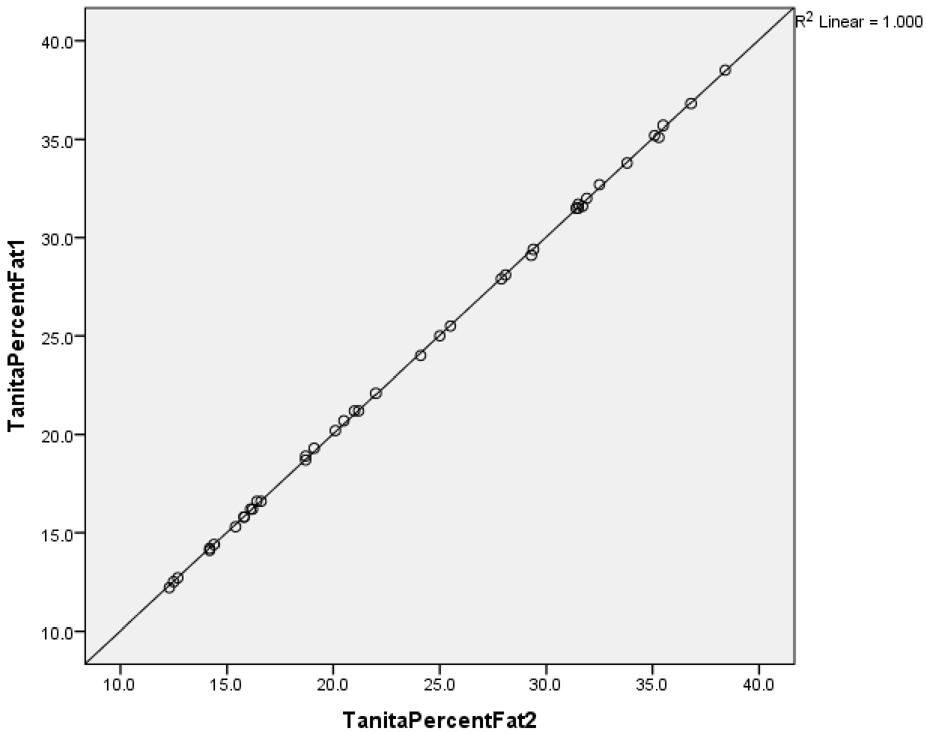

Figure 11. Relationship of trial 1 vs trial 2 of the Tanita for percent fat (p = 0.265).

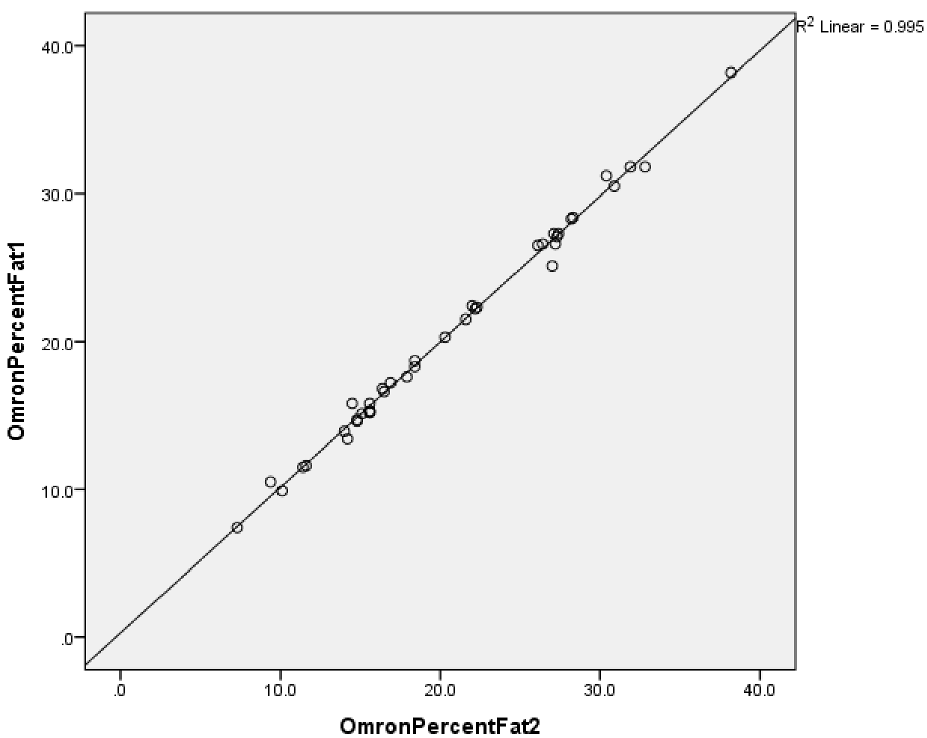

Figure 12. Relationship of trial 1 vs trial 2 of the Omron for percent fat (p = 0.720).

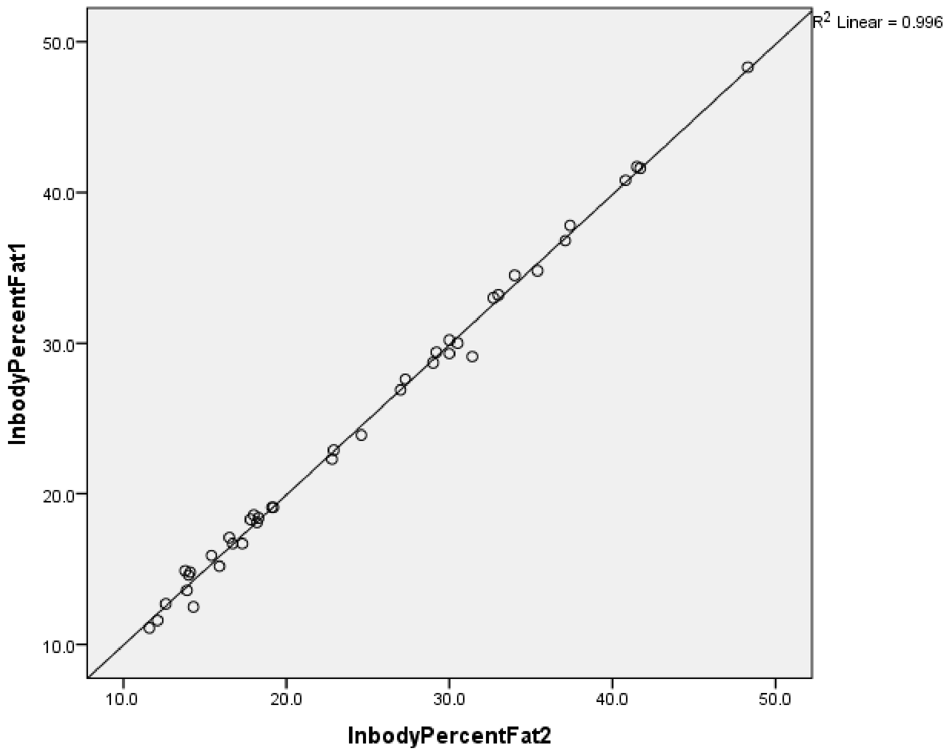

Figure 13. Relationship of trial 1 vs trial 2 of the Inbody for percent fat ($p = 0.376$).

Total body water was only measured by the Seca and Tanita BIA devices. Table 7 shows reliability for total body water for the two BIA devices based on two trials. The second trial on the Seca was significantly higher than the first trial by 0.2 l.

Table 7. Reliability of total body water (l) for the Seca and Tanita BIA devices (N = 40).

	Mean	Std. Deviation	P-values
Seca TBW trial 1	89.2	20.4	
Seca TBW trial 2 *	89.4	20.4	.046
Tanita TBW trial 1	90.0	19.9	
Tanita TBW trial 2	90.0	19.9	.323

*Indicates significant difference ($p < .05$)

Figures 14 and 15 illustrate the reliability for total body water for the Seca and Tanita devices. The r^2 values were 0.999 and 1.000 respectively, for the Seca and Tanita which is high.

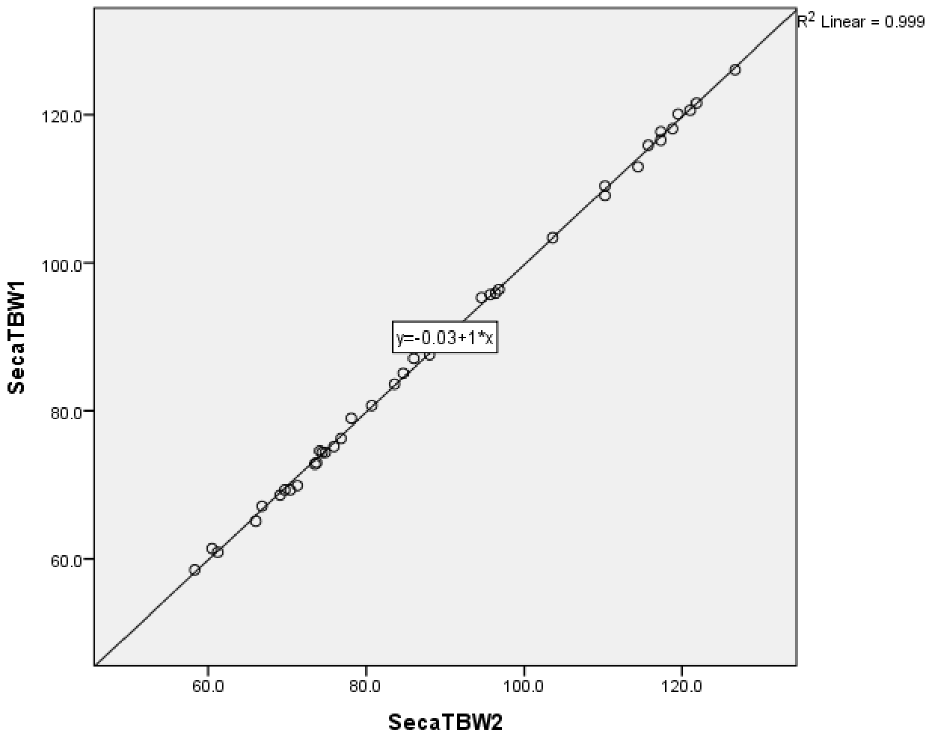

Figure 14. Relationship of trial 1 vs trial 2 of the Seca for total body water (p = 0.046).

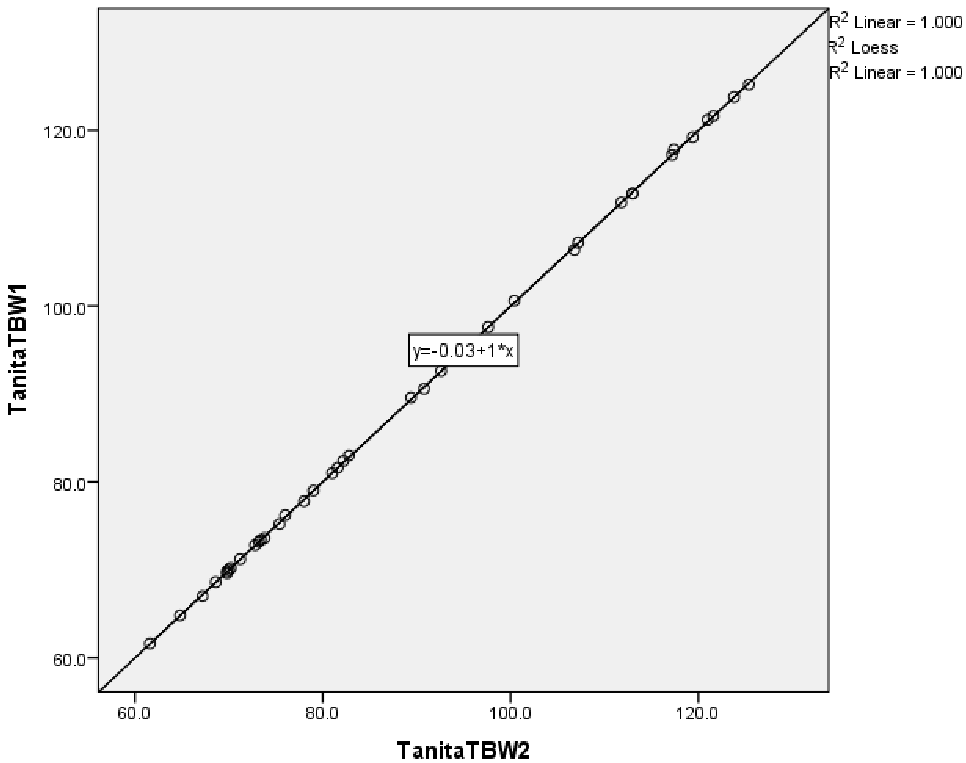

Figure 15. Relationship of trial 1 vs trial 2 of the Tanita for total body water ($p = 0.323$).

Gender Differences

Males

Tables 8-10 show results for males for percent fat, lean body mass, and total body water for each device.

For males, the Omron measured the lowest, while the Seca measured the highest mean percent fat. The Omron significantly ($p < .05$) underestimated percent fat vs the Seca, Tanita, and Inbody

Table 8. Mean body fat percent measured on all devices for males (N = 20).

	Mean	Std. Deviation	P-values vs Bod Pod
Bod Pod	16.8	7.7	
Seca *	18.4	6.3	.036
Tanita	18.0	5.1	.198
Omron	15.4	4.9	.201
Inbody	17.9	6.0	.137

*Seca significantly different from Bod Pod; Omron also significantly different from Seca, Tanita, and Inbody ($p < .05$).

For males, the Seca measured the lowest, while the Omron measured the highest lean body mass (kg). The Omron significantly ($p < 0.05$) overestimated lean mass vs the Seca, Tanita, and Inbody. The Seca significantly underestimated lean mass vs the Bod Pod.

Table 9. Mean lean body mass (kg) results measured on all devices for males (N = 20).

	Mean	Std. Deviation	P-values vs Bod Pod
BodPod	83.2	7.7	
Seca *	81.6	6.3	.036
Tanita	82.0	5.1	.198
Omron	84.6	4.9	.201
Inbody	82.1	6.0	.137

*Seca significantly different from Bod Pod. Omron also significantly different from Seca, Tanita, and Inbody ($p< .05$).

For males, total body water was higher on the Tanita than the Seca BIA device. However, this was not significantly different ($p = .469$).

Table 10. Mean total body water (l) measured on the Seca and Tanita BIA devices for males.

	Mean	Std. Deviation	N
Seca TBW	106.3	13.6	20
Tanita TBW	107.0	13.3	20

Females

Tables 11-13 show results for females for percent fat, lean body mass, and total body water for each device.

For females, the Omron measured the lowest, while the Bod Pod measured the highest percent fat. The Omron significantly ($p < .05$) underestimated percent fat compared to all other devices.

Table 11. Mean body fat percent for all devices for females (N = 20).

	Mean	Std. Deviation	P-values vs Bod Pod
Bod Pod	31.4	7.9	
Seca	30.7	7.2	.361
Tanita	29.2	6.3	.106
Omron *	25.6	5.7	.0001
Inbody	31.3	8.4	.949

*Omron significantly different from all others ($p < .05$).

For females, the Bod Pod measured the lowest, while the Omron measured the highest lean body mass (kg). The Omron significantly ($p < .05$) overestimated lean mass compared to all other devices.

Table 12. Mean lean body mass (kg) results measured on all devices for females (N =20).

	Mean	Std. Deviation	P-values vs Bod Pod
Bod Pod	68.6	7.9	
Seca	69.3	7.2	.361
Tanita	70.8	6.3	.106
Omron *	74.4	5.7	.0001
Inbody	68.7	8.4	.949

*Omron significantly different from all others ($p < .05$).

For females, the Tanita had a higher total body water than the Seca. However, this difference was not significant ($p = .507$).

Table 13. Mean total body water (l) measured on the Seca and Tanita devices for females.

	Mean	Std. Deviation	N
Seca	72.3	7.8	20
Tanita	73.1	5.7	20

CHAPTER V

DISCUSSION

The purpose of the current study was to determine the validity and reliability of various BIA devices compared to a criterion, the Bod Pod. It was hypothesized that there would be no significant differences in the various BIA devices as compared to the Bod Pod, for body composition (percent fat, lean body mass). The hypotheses of this study were partially refuted. There were significant differences among devices for some variables.

Validity

Percent Fat. For percent fat, the Omron significantly underestimated all other devices by about 4%. Based on r^2, the predictive validity of each BIA device vs the Bod Pod were high for the Seca and Inbody, while the Omron and Tanita were within acceptable limits. The results of this study are similar to Gartner et al. (2004) who found that the Omron underestimated percent fat by 8.8% in African American women. In contrast, Finn et al. (2015) compared the Inbody and Omron in children and adolescents and found body fat percentage to be higher on the Omron device than the Inbody for both males and females. This differs from the results found in the current study, where the

Omron significantly underestimated percent fat in young adults. Contradictory results may be due to age and race differences of the samples studied.

Device differences for the BIA results may also be due to the type of device and the areas through which the electrical current flows. The Omron is a handheld device which only measures upper body mass; the Tanita has foot plates, which only measures lower body mass; the Inbody and Seca have both handheld and foot sensors, which measure the impedance of the whole body.

Lean Body Mass. The Omron significantly overestimated lean body mass on all devices by about 4%. Based on r^2, the predictive validity was high for the Seca and Inbody, while the Omron and Tanita were within acceptable limits. Gartner et al. (2004) also found that the Omron overestimated lean body mass by 5.6 kg when compared to the Bod Pod in African American females.

Weight. For body weight, four of the five devices were compared, since the Omron does not measure weight. The Seca and the Inbody were significantly higher than the Bod Pod (the criterion) and Tanita, which did not differ. However, when compared against the Bod Pod, all BIA devices showed very high predictive validity ($r^2 = 1.000$ for each) for weight.

Total Body Water

There were no significant differences in total body water for the Seca and Tanita, the only two devices which measure this. However, the Tanita averaged higher total body water (0.7 L) when compared to the Seca.

Gender Differences

Results for males and females also analyzed separately to determine any gender differences between the devices. For males, the Omron underestimated percent fat by 1.4% for the Bod Pod, which was not significant. However, it significantly underestimated the other BIA devices (Seca, Tanita, Inbody). The Omron overestimated lean body mass for the Bod Pod, which was not significant. However, it significantly overestimated the other BIA devices (Seca, Tanita, Inbody). For total body water, there were no significant differences between the Seca and Tanita, the only devices which measure this variable.

For females, the Omron significantly underestimated percent fat and overestimated lean body mass as compared to all other devices. For total body water, there were no significant differences between the Seca and Tanita, the only devices which measure this variable.

Finn et al. (2015) compared children and adolescents on the Omron and Inbody. The results from their study showed a significantly higher body fat percentage on the Omron compared to the Inbody for both males and females. This contrasts the current study where the Omron significantly underestimated percent fat for both male and female adults. Contradictory results may be due to age differences of the samples.

Gender differences between the BIA devices may be due to the fact that females have less lean mass in their upper body than males, since the Omron measures impedance through hand-held sensors.

Reliability

Percent fat. Reliability of percent fat for trial 1 vs trial 2 was measured on all devices, with no significant differences found. The relationship of the first trial and the second trial on each BIA device was high, with r^2 ranging from 0.996 to 1.000. The results from this study show that reliability of each device is very high.

Total Body Water. For total body water, there was a significant difference between the first and second trial on the Seca, while the Tanita gave identical mean values. Bosy-Westphal et al. (2013) validated the Seca for body composition in males and females, ages 18-65 years. Their study was conducted in two phases where they first developed a BIA equation, and secondly validated that equation. The researchers found the Seca to be a valid tool to estimate total body water in adults.

CHAPTER VI

SUMMARY AND CONCLUSION

The hypothesis of this study was partially refuted due to significant differences among devices for some variables. The results of the current study showed a significant underestimation of body fat percentage and overestimation of lean body mass, by the Omron compared to all other devices. Weight was significantly higher for the Seca and Inbody vs the Bod Pod and Tanita. No significant differences in total body water were found for the Seca and Tanita.

The Seca and Inbody had the highest predictive validity when compared to the Bod Pod. The Tanita had acceptable validity but the Omron is not recommended for body composition assessment. With new BIA devices appearing on the market, more research is needed in order to determine if there is a better criterion measure than the Bod Pod.

Application

A variety of BIA devices are commonly used in exercise science laboratories and wellness companies for measuring body composition in a safe and quick manner. The results of this study can be useful in helping professionals determine which device will be the most valid and cost effective.

Limitations

Limitations of this study were as follows:

1. Trusting that the subjects were fasted for the appropriate amount of time, and normally hydrated for the testing;
2. Mostly Caucasian subjects;
3. Young adult sample;
4. Even though the "athletic mode" on the Tanita has been found to be more accurate in this laboratory, this may not have been the case for all subjects;
5. It should be noted that one subject had an implantable device for diabetes, but this did not seem to affect the outcome of his results.

Future Research Recommendations

1. Including the DEXA to be compared against the Bod Pod and BIA devices for validity;
2. Conducting the study with more diverse ethnic groups;
3. Including different age groups;
4. Since implantable devices (other than pacemakers) are becoming more prevalent, determine their effect on body composition results by different methods.

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Appendix A

CLEVELAND STATE UNIVERSITY

October 2, 2018

Dear Kathleen Little,

RE: IRB-FY2019-19

Validity of Various BIA Devices vs the Bod Pod for Body Composition

The IRB has reviewed and approved your application for the above named project, under the category noted below. Approval for use of human subjects in this research is for a one-year period as noted below. If your study extends beyond this approval period, *you must contact this office to initiate an annual review of this research.*

Approval Category: Expedited Category 4

Approval Date: October 2, 2018

Expiration Date: October 1, 2019

By accepting this decision, you agree to notify the IRB of: (1) any additions to or changes in procedures for your study that modify the subjects' risk in any way; and (2) any events that affect that safety or well-being of subjects. Notify the IRB of any revisions to the protocol, including the addition of researchers, prior to implementation.

Thank you for your efforts to maintain compliance with the federal regulations for the protection of human subjects. Please let me know if you have any questions.

DO NOT REPLY TO THIS EMAIL. IF YOU WISH TO CONTACT US, PLEASE SEND AN EMAIL MESSAGE TO cayuseirb@csuohio.edu.

Sincerely,

Mary Jane Karpinski

IRB Analyst

Cleveland State University

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Appendix B

Cleveland State University

engagedlearning

College of Education and Human Services

Department of Health and Human Performance

INFORMED CONSENT FOR PARTICIPATION

Validity of Various Bioelectric Impedance Analysis (BIA) Devices

vs the Bod Pod for Body Composition

Introduction

Thank you for considering to be a part of this study. My name is Alivia Stephan and I am working on my Master's Thesis at Cleveland State University (CSU). This study will be conducted under the supervision of Dr. Kathleen Little, Associate Professor of Exercise Science in the Health and Human Performance Department.

The purpose of this study is to determine how valid various bioelectrical impedance analyzers (BIA) are compared to a laboratory method, the Bod Pod. We will specifically look at percent fat, fat mass, lean mass, and total body water from the BIA devices. The research study will be conducted in the Human Performance Laboratory (HPL) at CSU.

Procedures

40 healthy males and females will be tested. You will be assigned to a random testing order on each of the devices. You will be informed to wear tight fitting clothing (compression shorts, and sports bras for females) and no jewelry. You will also be told to be normally hydrated, but have not eaten for at least 4 hours. You will be tested on the Bod Pod, Seca, InBody, Tanita, and Omron BIA devices. Tests on each device will be done twice for accuracy. You will only be asked to come to the HPL one time for this study. Testing will take one hour.

Before entering the BodPod, you will place a swim cap over your hair. You will then sit inside the Bod Pod and breathe normally for the first measurement. This measurement will take less than a minute. When the first measurement is complete, the door will be opened, and then closed again to begin the second measurement. If a third measurement is needed, the procedures will be repeated.

For the Seca device, you will step onto the device. You will then place your hands on the hand holds and stand still until the measurement is completed. This measurement takes about one minute. These procedures will be repeated once for accuracy.

For the Inbody device, you will step onto the device. You will then hold the handles with your arms straight and out to the side, not touching your body. You will stand still until the measurement is completed. This measurement will take about one minute. These procedures will be repeated once for accuracy.

For the Tanita device, you will step onto the device with your feet on the sensors. Once the meausurement is complete, you will step off the device. This measurement will take about 30 seconds. These procedures will be repeated once for accuracy.

For the Omron device, you will stand with your feet slightly apart and grip the electrodes on the device. You will then extend your arms in front of your body. Once you are in this position, the researcher will press "start" to begin the test. When the measurement is complete, you will relax your arms. These procedures will be repeated once for accuracy.

Risks

Risks of these tests are minimal. You may feel some anxiety while in the Bod Pod if you have a fear of enclosed spaces. The capsule has a window which lets in light and allows you to see out. There is also a "panic button" that will release the magnets and open the door if you feel uncomfortable at any time during the test. There are no known risks associated with the various BIA devices.

Benefits

I understand that there are no direct benefits to me for participating in this study other than the knowledge of my percent fat, fat mass, lean mass, and total body water. The results of this study will be beneficial to exercise science laboratories and wellness companies who measure body composition.

Confidentiality

To protect privacy, data obtained during my participation will be confidential. A number will be assigned to me in place of a name. The information may be used for statistical or scientific purposes with the right of privacy retained. Only research staff will have access to the data, which will be stored in the HPL (PE 60B) in a locked file cabinet.

Participation

I understand that participation in this project is voluntary. I have the right to withdraw at any time with no consequences. I attest and verify that I have no known health problems that would prevent me from successfully participating in the testing. If I have any questions about the procedures, I can contact Dr. Kathleen Little at (216) 687-4877 (k.d.little@csuohio.edu) or Alivia Stephan at (419) 722-0712 (a.stephan13@vikes.csuohio.edu).

I understand that if I have any questions about my rights as a participant, I can contact Cleveland State University's Review Board at (216) 687-3630.

Participant Acknowledgement

The procedures, purposes, known discomforts and risks, possible benefits to me and to others have been explained to me. I have read the consent form or it has been read to me, and I understand it. I also understand that all data, even data collected to determine eligibility for the study, will be stored in a secured file in the HPL for at least 3 years, then will be destroyed.

I agree to participate in this study. I am at least 18 years of age.

I have been given a copy of this consent form.

Signature:______________________________________ Date: ____________

Name Printed:__________________________________

Witness:____ Date:____________

Appendix C

Cleveland State University
engagedlearning
College of Education and Human Services
Department of Health and Human Performance

Body Composition Research Study

-Are you 18 to 35 years old?

-Interested in finding out your percent fat, fat mass, lean mass, and total body water?

We are looking for participants to take part in a research study for Alivia Stephan's Master's thesis under the direction of Dr. Kathleen Little at Cleveland State University, to determine how valid various bioelectrical impedance analyzers are compared to the Bod Pod.




If you are interested in participating in this study please contact Alivia Stephan at a.stephan13@vikes.csuohio.edu or (419)722-0712.

Appendix D

Questionnaire

Name: **Date:** **Age:**

Prosthetics or Implantable Devices

Please check each box that applies to you.

- ☐ No prosthetic devices
- ☐ No implantable devices such as a pacemaker
- ☐ No implanted metal
- ☐ No plates or screws within the body

Exercise History

1. Are you a competitive athlete?
    a. If so, indicate sport and level (ie. College, recreational, etc.)
2. If you exercise regularly, indicate the following:
    a. Type of activity
    b. Frequency (days per week)
    c. Duration (minutes per day)
    d. Intensity (low, moderate, high)

Females Only:

Menstrual Cycle

Please indicate the start date, to the best of your knowledge, of your last menstrual cycle.

____

Appendix E

Bod Pod

Seca

Inbody

Tanita

Omron

Appendix F

Data Sheet

ID: Date:

Bod Pod

Tanita

Trial 1	
Trial 2	

Omron

Trial 1	
Trial 2	

Seca

Trial 1	
Trial 2	

Inbody

Trial 1	
Trial 2	