All Theses and Dissertations

2016-06-01

Validity and Reliability of a Photographic Method of Assessing Body Composition

Elizabeth Z. MacDonald
Brigham Young University

Follow this and additional works at: https://scholarsarchive.byu.edu/etd

Part of the Exercise Science Commons

Validity and Reliability of a Photographic Method of Assessing Body Composition

Elizabeth Z. MacDonald

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

Pat R. Vehrs, Chair
Ronald L. Hager
James D. George

Department of Exercise Sciences

Brigham Young University

June 2016

ABSTRACT

Validity and Reliability of a Photographic Method of Assessing Body Composition

Elizabeth Z. MacDonald
Department of Exercise Sciences, BYU
Master of Science

The LeanScreen[TM] app uses photographs and touchscreen technology of an iPad or iPhone to estimate body composition using the Department of Defense (DoD) prediction equations that use cirumference measurements of the neck, abdomen, waist, and hips. The purpose of this study was to determine the validity and reliability of the LeanScreen[TM] app in 148 weight-stable adults (82 men, 66 women) who were normal weight, overweight, or obese as defined by body mass index. The percent body fat (%BF) of each subject was estimated during one visit using dual-energy x-ray absorptiometery (DXA) as the criterion measure, and three field methods: the LeanScreen[TM] app, manually measured circumferences, and an OMRON bioelectical impedance (BIA) device. The %BF of each subject was determined once using DXA. Each of two administrators assessed the %BF of each subject twice using the LeanScreen[TM] app, manually measured circumferences, and the OMRON BIA device. When using the LeanScreen[TM] app, administrators assessed body composition using photographs they had taken and the photographs taken by the other administrator.

Validity was established by comparing estimates of %BF from the LeanScreen[TM] app, manually measured circumferences, and the OMRON BIA device to %BF values obtained from DXA. Inter- and intrarater reliability was determined using mutliple measurements taken by each of two administrators. The three field methods were compared to DXA using mixed model ANOVA and Bland-Altman analyses. Analysis of the data revealed that the LeanScreen[TM] app, manually measured circumferences, and the OMRON BIA device significantly underestimated ($p < 0.05$) the %BF determined by DXA by an average of -3.26 ± 3.57 %BF, -4.82 ± 3.45 %BF, and -8.45 ± 3.48 %BF, respectively. Limits of agreement (LOA) for the LeanScreen[TM] app (6.99 %BF), manually measured circumferences (6.76 %BF), and the OMRON BIA device (6.82 %BF) were large. Slopes of the line-of-best-fit through the data in the Bland-Altman plots indicate that bias of %BF estimates using the LeanScreen[TM] app (slope = 0.06; $p = 0.008$) and the OMRON BIA device (slope = 0.15; $p <0.0001$) increased as %BF increased. For each method of assessment, minimal variance could be attributed to different administrators peforming the assessment and each administrator performing multiple assessments. All inter- and intrarater reliability coefficients of the LeanScreen[TM] app, manually measured circumferences, and OMRON BIA estimates of %BF exceeded 0.99. The results of this study indicate that all three field methods of body composition assessments were highly reliable, however, these field measures are not recommended for use in the assessments of %BF due to a significant bias and large limits of agreements.

Keywords: obesity, percent body fat, total body fat, OMRON, DXA, circumferences

ACKNOWLEDGMENTS

The chance to work on one major research project from start to finish became an irreplaceable experience during my education. I would like to thank my graduate committee, Dr. Hager and Dr. George, and statistical consult, Dr. Eggett, for their insight and assistance. The time and energy of my two wonderful research assistants, Nicole Brown and Jami Hamblin, was invaluable when processing so many subjects. I am grateful for the funding from LeanScreen™ which made this project possible.

Both my experience in the graduate program and in research would not have been possible had it not been for the mentorship of Dr. Vehrs. His encouragement, guidance, and patience helped me to navigate my path to where I am today. The efforts and support of Barb Hehl and Maggie Shibla were a major help to ultimately complete the graduate program. I am indebted to the many professors and peers who pushed me to become better than I knew possible in the areas of academics, research, and working in the field. Lastly, I am grateful for the support and love of my husband, Luke, who never stopped believing in me.

Table of Contents

List of Tables

List of Figures

Introduction

Body mass index (BMI) is frequently used to classify an individual into a weight category for their respective height. National Health and Nutrition Examination Survey (NHANES) data indicate that over two thirds of adults are overweight or obese, as defined by a BMI of > 25 kg/m^2 (Ogden, Carroll, Kit, & Flegal, 2013, 2014). Excess body mass is associated with increased risk of cardiovascular diseases (CVD), type II diabetes mellitus, hypertension, dyslipidemia, stroke, gallbladder disease, osteoarthritis, sleep apnea and respiratory problems, and some cancers (Heyward, Wagner, & Dale R., 2004; National Institute of Health, 1998.). Overweight and obesity are also associated with a decreased quality of life and higher rates of mortality (Heyward et al., 2004).

Although BMI can be a useful health screening tool and indictor of risk for lifestyle-related diseases, it does not differentiate between fat and lean body mass. Various methods of assessing body composition are available for use in different settings. Criterion measures of body composition such as dual-energy x-ray absorptiometry (DXA) and air displacement plethysmography are expensive, require special equipment and extensive training of technicians, and are most often only available in laboratory, clinical, or research settings. Garrow and Webster (1985) suggested the consideration of five factors when selecting a method of assessing body composition in the field: cost, operator training, maintenance cost, precision, and accuracy. Some publicly available, inexpensive methods of estimating body composition include the use of skinfold measurements, circumferences, and hand-to-hand or hand-to-foot bioelectrical impedance analyzers (BIA). These "field" methods are efficacious for use in public schools, the military, community, and corporate fitness centers.

Recently, an easy-to-use iOS application called LeanScreen™ (hereafter referred to as LeanScreen; PostureCo Inc, Trinity, FL, USA) uses two photographs and touch screen technology to identify landmarks on the neck, waist, abdomen, and hips on frontal and sagittal view photographs (Posture Co Inc, 2014). Mathematical models are then used to estimate circumferences of the neck, waist, abdomen, and hips. Percent body fat (%BF) is predicted using estimated circumferences and the gender-specific regression equations used by the Department of Defense (DoD) to estimate body composition of military personnel (US Department of Defense, 2013). The LeanScreen app is designed for use on both the iPhone and iPad and is publicly available for less than $15. If accurate, the LeanScreen app could be the means by which fitness professionals in a variety of settings could provide timely and cost-effective body composition information to clients with minimal operator training. Storage of photographs and data on the iOS device allows tracking of body composition data over time. Although the iOS app is publicly available, the validity and reliability of estimates of %BF using the LeanScreen app have yet to be established. Therefore, the purposes of this study were to (a) evaluate the validity of estimated %BF from the LeanScreen app, manually measured circumferences and the DoD regression equations, and the OMRON BIA device compared to DXA as the criterion measure, and (b) evaluate the reliability of estimated %BF from the same three methods.

Methods

Subjects

One hundred and forty-eight weight-stable subjects (82 men, 66 women) 18–50 years of age participated in this study. Women who were pregnant and men or women who self-reported being anemic, anorexic, or bulimic, currently being treated for an illness, or having signs of edema were excluded from participation in this study. In addition, individuals who were

2

currently taking prescribed medications of any type, or taking weight loss supplements or on a weight loss program were excluded from participation. Female subjects were not pregnant, were more than 6 months postpartum, and between days 5 and 14 of their menstrual cycle. Subjects were recruited from the university campus community of students, staff, and faculty using flyers and classroom announcements. To evaluate the validity and reliability of %BF predictions in subjects of different body sizes, approximately one-third of the subjects were recruited in each of three BMI categories: normal weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obese (30–35 kg/m^2). An a priori power analysis was performed to determine an appropriate sample size for this study. Using an alpha of 0.05, a beta value of 0.20 (power of 80%), a standard deviation of 3 %BF within each BMI category, and a significant difference of 3.5 %BF between the methods of assessing body composition (Weaver, Hill, Andreacci, & Dixon, 2009), the analysis indicated that a total sample size of 144 subjects was needed to evaluate differences in estimates of %BF between devices and groups.

Procedures

This study was reviewed and approved by the University Institutional Review Board for Human Subjects prior to the collection of data. Subject's participation in this study included one visit to the lab. After being informed of study procedures, risks, and benefits of their participation in the study, each subject provided voluntary written informed consent and completed a preparticipation questionnaire that included questions about inclusion and exclusion criteria.

The %BF of each subject was assessed once using DXA. Each of two administrators assessed %BF two times using the LeanScreen app, a handheld OMRON BIA device (Model HBF306CN; Omron HealthCare, Inc., Lake Forest, IL, USA), and manually measured

3

circumferences of the neck, abdomen, waist, and hips. The order of which administrator performed the measurement first was randomized. Validity of the LeanScreen app, manually measured circumferences, and the OMRON BIA device was determined by comparing estimates of %BF to the %BF obtained from DXA. Data collected from the two trials by each of the two administrators were used to determine inter- and intra-administrator reliabilities of the LeanScreen app, manually measured circumferences, and the OMRON BIA device. Each administrator used the LeanScreen app to estimate %BF of the subject using the set of photographs taken by that same administrator as well as a set of photographs taken by the other administrator. Each administrator also estimated %BF of the subject a second time using their own first set of photographs a day later. Thus, the reliability of estimates of %BF using the LeanScreen app considered the use of the same photos by two administrators and the reliability of estimates of %BF using different photos taken by the same administrator.

Male subjects wore a pair of spandex shorts and female subjects wore either a form-fitting one-piece bathing suit or a pair of spandex shorts and a sports bra. All anthropometric measurements and assessments of body composition were made with subjects in this attire.

Manually Measured Circumferences

Height was measured in centimeters using a calibrated wall-mounted stadiometer scale (SECA Model 264; SECA, Cino, CA, USA) to the nearest one-tenth of a centimeter. Body mass was measured and recorded using a digital scale (Ohaus Model CD-33, Ohaus Corporation, Pine Brook, NJ, USA) to the nearest one-tenth of a kilogram. BMI (kg/m^2) was calculated from measured height and body mass values.

Circumference measurements followed the instructions provided by the DoD (US Department of Defense, 2013). All circumference measurements were recorded in inches to the

4

nearest one-eighth inch using a spring-loaded Gullick measuring tape. Neck, abdomen, waist, and hip circumferences were measured on all subjects. The measuring tape was applied to make contact with the skin and conform to the contour of the body surface. The use of the Gullick spring-loaded measureing tape was used to assure consistent measurements without overly compressing the underlying soft tissues. The circumference of the neck was measured just below the larynx and perpendicular to the long axis of the neck. The abdomen was measured at the level of the naval with the tape measure parallel to the floor at the end of a normal, relaxed expiration. The waist measurement was measured at the natural, or place of minimal abdominal circumference at the end of a normal relaxed exhalation. If a natural narrowing of the waist was not evident, the waist circumference was measured at the smallest circumference between the naval and lower end of the sternum. The hip circumference was taken at the greatest protrusion of the gluetal muscles as viewed from the side, with the tape measure parallel to the floor.

In each trial, all circumferences were taken sequentially, then repeated a second and third time. The three measurements were averaged and rounded according to instructions provided by the DoD (US Department of Defense, 2013). Height measurements were rounded to the nearest one-half inch. Average circumference of the neck was rounded up to the nearest one-half inch. Average circumferences of the abdomen, waist, and hips were rounded down to the nearest one-half inch. Rounded average values were used in the following DoD gender-specific anthropometric equations (US Department of Defense, 2013):

For women:

% body fat = [163.205 x Log10 (waist + hip − neck)] − [97.684 x Log10 (height)] − 78.387

For men:

% body fat = [86.010 x Log10 (abdomen – neck)] − [70.041 x Log10 (height)] + 36.76

where height and circumference measurements are in inches.

Bioelectrical Impedance

The handheld OMRON BIA device uses proprietary algorithms to estimate body composition based on the measured resistance (*R)* value, age, gender, body mass, height, and body type (athlete or normal). The manufacturer recommendations were followed in selecting the correct body type for each subject. After entering the subject's age, gender, body mass, height, and body type, the subject was asked to stand with feet hip-width apart. Subjects firmly grasped the two-grip electrodes and held the OMRON BIA device in front of their body with the arms fully extended and parallel to the floor. In this position, the administrator pressed the start button and then recorded the %BF value from the digital display. This assessment took 1–2 minutes to complete.

Dual-Energy X-Ray Absorptiometry

The General Electric Lunar iDXA (GE Medical Systems Lunar, Madison, WI, USA) was used to perform a single whole-body scan to assess body composition in all subjects. A state certified DXA technician followed the manufacturer-recommended operating procedures for whole-body scans. The same technician analyzed all scans to determine %BF of each subject.

LeanScreen

The LeanScreen app was used to take two pictures of each subject: one from the front and one from the right side. A tape mark was placed on the floor indicating where the subject was to stand when the photographs were taken. Each administrator stood on a tape mark 3 meters away from the subject. Photographs were taken so that the top of the head and feet were visible. The

6

LeanScreen app uses a zoom-in tool and prompts the administrator to mark specific landmarks with the touchscreen of the iPad. Using the photograph from the frontal view, the administrator marked the left and right borders of the neck just below the larynx. The LeanScreen app automatically connects the two landmarks with a line. The landmarks can be adjusted as needed to assure that the line is horizontal. In the same manner, the administrator marked the left and right borders of the abdomen (level of the naval), the waist (smallest circumference of the torso), and the hips (greatest protrusion of the gluteal muscles). Using the photograph from the right lateral view, the administrator marked the anterior and posterior borders of the neck below the larynx and perpendicular to the long axis of the neck, abdomen, waist, and hips. The LeanScreen app displays the predicted %BF values calculated from the same equation used by the DoD to predict %BF from manually measured circumferences (US Department of Defense, 2013).

Statistical Analysis

Gender differences in age, height, body mass, BMI, circumfrences, and waist-to-hip ratio (WHR) were determined using one-way ANOVAs and the Bonferroni correction for the critical t value and associated critical p value for multiple tests. The validity of estimates of %BF using the LeanScreen app, manually measured circumferences, and the OMRON BIA device were determined by comparing estimated values to the criterion measure of %BF from DXA. For this analysis, a mixed model ANOVA was used to accommodate multiple sources of variability when each subject has multiple observations from each method of body composition assessment. The dependent variable was the difference between the estimate of %BF from the prediction method and the criterion measure of %BF from DXA. The ANOVA was blocked on subjects to account for the correlation between the multiple observations of each subject with each method. As subjects were classified as either normal weight, overweight, or obese, BMI category was

7

included as an independent variable. An a priori alpha level was set at 0.05. Significant differences were determined after correcting the critical t value and associated p value for multiple tests. All statistical analyses were performed using SAS statistical software (version 9.4).

The agreement between the estimates of %BF using the prediction methods and the %BF estimated from DXA were further evaluated using Bland-Altman analyses (Bland & Altman, 1986). Bland-Altman analyses include plots of the bias between the estimates of %BF from each prediction method and DXA (y-axis) against the mean of the two estimates (x-axis) and the limits of agreement (LOA) of the method considered to be the prediction method. In this study, the %BF value obtained from DXA was subtracted from the %BF obtained from the prediction method, so a positive bias represents an overestimation by the prediction method. The LOA were calculated as the average bias $\pm$ 1.96 SD (Bland & Altman, 1986). The ideal agreement, for example, between estimates of %BF using the LeanScreen app and DXA would produce a Bland-Altman plot with a bias (y-axis) that is not significantly different from zero and a line-of-best-fit that is consistent (slope = 0) across the range of percent body fat values (x-axis). The slope of the line-of-best-fit through the data in each Bland-Altman plot was determined and compared to zero. The proportion of subjects whose estimated %BF value fell within various ranges of the criterion measure was determined using a frequency distribution of the differences between the estimates of %BF and DXA.

Inter- and intrarater reliability of estimates of %BF for each prediction method were evaluated and sources of variation in the model were estimated for each method separately. The sources of variation were subject-to-subject variability, administrator-to-administrator (interrater) variability, and trial-to-trial (intrarater) variability. The subject-to-subject variability served as

8

our base when estimating both the administrator-to-administrator and the trial-to-trial reliability. The reliability estimates are the difference in the subject-to-subject variance estimate and the rater-to-rater or trial-to-trial variance estimate relative to the subject-to-subject variance. For the LeanScreen app estimates of %BF, we also estimated the reliability of using a photo taken by a different rater to estimate %BF. This was done as described above using the variability from different ratings of the same photo.

<div align="center">Results</div>

The subjects in this study included 31 males and 30 females in the normal weight BMI category, 32 males and 28 females in the overweight BMI category, and 19 males and 8 females in the obese BMI category. Subject descriptive information is shown in Table 1. One-way ANOVAs revealed that males were signficantly ($p < 0.001$) taller and heavier than their female counterparts in each of the BMI categories (Table 1). There were no systematic differences in circumferences between men and women between the three BMI categories. Overweight and obese females had lower WHR values ($p < 0.001$) than their overweight and obese male counterparts (Table 1). Even though males and females had similar BMI values, females had significantly ($p < 0.001$) higher %BF values than their male counterparts in each BMI category (Table 1).

Estimates of %BF from each method are shown in Table 2. All methods produced %BF values that were on average higher in females than in males ($p > 0.05$). The mixed model ANOVA revealed that compared to DXA, the LeanScreen app, manually measured circumferences, and the OMRON BIA device significantly underpredicted %BF (Table 2). The difference in %BF between each of the methods and DXA were not influenced by gender ($p = 0.6839$) and BMI category ($p = 0.8081$). The bias and LOA typically calculated to generate

Bland-Altman plots are also shown in Table 2. Bland-Altman plots for each method are shown in Figures 1, 2, and 3. The Bland-Altman plot for estimates of %BF using manually measured circumferences indicates that the DoD equations underestimated DXA %BF by an average of −4.82 %BF (Figure 1). As the slope (0.002) of the line-of-best-fit through the data was not significantly different from zero ($p = 0.8987$), the bias was consistant across the range of %BF values (*x*-axis). The Bland-Altman plot (Figure 2) indicates that using the LeanScreen app to estimate %BF from photographically determined circumferences and the the DoD equations underestimated DXA %BF by an average of −3.26 %BF. A significant slope (0.06; $p = 0.008$) of the line-of-best-fit through the data indicates that the bias increases as %BF increases. The Bland-Altman plot (Figure 3) indicates that the OMRON BIA device understimated DXA %BF by an average of −8.45 %BF. A significant slope (0.15; $p < 0.0001$) of the line-of-best-fit through the data indicates that the bias increases as %BF increases. The proportion of subjects whose estimated %BF value fell within various ranges of the criterion measure appear in Table 3.

Sources of variance of each method of measurement is shown in Table 4. As expected, the largest source of error for each method was between the subjects themselves. For each method of assessment, minimal variance could be attributed to different administrators performing the assessment and each administrator performing multiple assessments. Likewise, minimal variance could be attributed to using the LeanScreen app and a photograph taken by another administrator to estimate body composition. The reliability coefficients for inter- and intrarater reliability of the LeanScreen app, circumferences, and OMRON estimates of %BF and the reliability coefficient for using a photograph taken by another administrator to estimate %BF with the LeanScreen app all exceeded 0.99.

10

Discussion

The persistant emphasis to reduce the prevalence of obesity makes it necessary to establish the validity and reliability of field methods to assess body composition in settings most accessible to the general public (e.g., worksite health promotion programs, local fitness centers, schools). In these settings, methods should be easy to use, affordable, and accessible by health and fitness professionals. Valid and reliable methods are necessary to accurately assess health risks associated with overweight and obesity and to monitor the influence of diet and exercise interventions over time. This is the first study to evaluate the validity and reliability of the LeanScreen app which uses photographs and touch screen technology to estimate body composition using the DoD circumferences equations. In this study, we evaluated the validity and reliability of estimates of body composition using the LeansScreen app, manually measured circumferencces, and the OMRON BIA device, which is approximately equal in cost, ease of use, and availability as the LeanScreen app. This study is unique in that multiple estimates of %BF were compared to the estimates of %BF derived from DXA in 148 adult normal weight, overweight, and obese men and women. The results of this study indicate that the accuracy of estimates of %BF using the LeansScreen app, manually measured circumferencces, and the OMRON BIA device was not influenced by gender or BMI category. Although all methods were highly reliable, all three field methods significantly underestimated the %BF determined by DXA in men and women across a wide range of BMI values.

Manually Measured Circumferences

The DoD includes an assessment of body composition as part of its screening for physical readiness and to identify personnel who need to modify nutrition and exercise habits. The development of the DoD circumference equations (Hodgdon & Friedl, 1999) resulted in

11

acceptable performance of regression equations to predict %BF in 594 men (R = 0.903, SEE = 3.52 %BF) and 202 women (R = 0.856, SEE = 3.61 %BF). When the estimates of %BF from the DoD equations were compared to those from a 4-compartment model, the average bias and standard error of measurement (SEM) in men (bias = −0.83 %BF, SEM = 3.15 %BF) and women (bias = −2.0 %BF, SEM = 3.12 %BF) were resonable. When the estimates of %BF were compared to those from a 2-compartment model, the results were similar in men (bias = −1.25 %BF, SEM = 3.37 %BF) and women (bias = −3.22 %BF, SEM = 4.15 %BF). The results of the current study are contrary to those reported by Hodgdon and Friedl (Hodgdon & Friedl, 1999) in that use of manually measured circumferences in the DoD equation significantly underestimated DXA %BF by an average of −4.82 ± 3.45 %BF (Table 2; Figure 1) and only 41% of the estimates of %BF were within ± 4 %BF of the criterion measure (Table 3). Based on the large bias in predictions of %BF, use of the gender specific DoD circumference equations is not recommended in field settings.

The anthropometric equation to predict percent body fat in males was evaluated on its ability to track changes in %BF in 21 male Army cadets over a 9-month period of time (Schuna J.M., Hilgers-Greterman S.J., Manikowske T.L., Tucker J.M., & Liguori G., 2013). Air-displacement plethysmography (ADP) was used as the criterion measure of %BF. Over a 9-month period of time %BF and fat mass (FM) as measured by ADP increased by 2.1% body fat and 1.9 kg, respectively, while %BF and FM as measured by the DoD equation increased by only 0.3 %BF and 0.4 kg, respectively. The results indicate that the DoD equation for men underestimated %BF in comparison to ADP and was unable to track changes in body composition with a small gain in body mass.

Error in predicting body composition from circumferences may be introduced by the use of different tape measures to measure circumferences, differences in measurements locations, and experience and abilities of the test administrator. In this study, both administrators used a Gullick spring-loaded measuring tape to standardize the tension applied to the measuring tape when measuring circumferencs. Males and females in this study wore form-fitting clothing to improve the ability to identify anatomical landmarks and eliminate error that might be introduced by wearing loose clothing.

LeanScreen

The LeanScreen app underestimated %BF in men and women (Table 2). As this is the first study to report the validity and reliability of estimates of %BF using the LeanScreen app, it is not possible to compare the results of this study to results of previous studies. Use of the LeanScreen app to estimate %BF resulted in a bias of −3.26 %BF and a wide LOA (Table 2; Figure 2). While estimates of %BF from both manually-measured circumferences and the LeanScreen app are based on the same DoD equations, the bias in the LeanScreen app was 1.5%BF (32%) less than for manually measured circumferences. Only 60% of the estimates of %BF fell within ±4 %BF of the criterion measure (Table 3). Data from this study suggest that the LeanScreen app cannot currently be recommended to estimate %BF when the accurate assessment of body composition of an individual is necessary. As the LeanScreen technology is in its infancy, it is foreseeable that additional research and product development could lead to the refinement of the proprietary algorithms used to estimate body composition.

The touchscreen technology used by the LeanScreen app to identify anatomical landmarks and circumferences of neck, abdomen, waist and hips is innovative and promising. The use of this technology and the zoom feature of the app is of practical importance to preserve

13

client privacy by the elimination of palpation of anatomical landmarks. In this study, male subjects wore only spandex shorts so the waist and abdomen were bare. Women wore either a form fitting one-piece bathing suit or spandex shorts and a sports bra. Nevertheless, because bias was observed in spite of the fact that subjects wore minimal and form fitting clothing, we expect that assessing body composition of individuals who are fully clothed (i.e., wearing pants, loose shorts, t-shirts, blouses, etc.) could potentially introduce greater bias and variability in estimates of %BF. Future studies could evaluate the validity of estimates of %BF in subjects who are fully clothed.

It is difficult to explain the bias reported in this study between the LeanScreen app and DXA without knowing the details of the algorithms used to convert data obtained from photographs to estimates of circumferences used to predict %BF. Based on the differences in bias, it may appear that the LeanScreen app is an improvement to using manually measured circumferences to estimate body composition. Nevertheless, the use of touch screen technology may introduce a source of error in and of itself. In this study, as noted by the slope of the line-of-best-fit through the data in the Bland-Altman plot (Figure 2), the magnitude of the underestimate of %BF increased as %BF increased. It should be noted that the bias in the estimate of %BF using manually measured circumferences was consistent across the range of %BF values (Figure 1). The additional error introduced by the LeanScreen app as %BF increases may be due to a greater difficulty in identifying anatomical landmarks (e.g., waist, abdomen, and hips) from photographs compared to manually measured circumferences. Some error may simply be due to the size of the finger print in using a touch screen. The use of a fine-tip stylus or a higher resolution zoom feature may reduce variability in marking anatomical landmarks. Errors may also occur if the camera is positioned incorrectly relative to the subject. For the most accurate

data, the camera must be positioned square to the subject. In this study, photos were taken with subjects standing on the same marked area of the floor with the iPad camera directly in front and perpendicular to them.

Estimates of body composition using the LeanScreen app and manually measured circumferences were highly reliable (Table 4). In this study, we evaluated the trial-to-trial (intrarater) reliability as well as interrater reliability between two test administrators. The LeanScreen app saves photos of subjects so the photos can be reevaluated on a later date by the same test administrator or a different test administrator. In this study, the reliability of a test administrator evaluating photographs taken by themselves a second time or evaluating a photograph taken by a different test administrator was excellent. The data from this study suggest that the LeanScreen app can be used to estimate body composition of a given individual by multiple administrators. This has practical application in settings such as corporate or community-based health promotion and fitness programs.

Bioelectrical Impedance

The results of this study indicate that the OMRON BIA device underestimated the criterion measure of body compositon by 1.75–2.6 times that of manually measured circumferences and the LeanScreen app (Table 2). The large bias and LOA found in this study add to the mounting evidence suggesting that the hand-to-hand OMRON BIA device should not be used when seeking accurate assessments of body composition in the field. Previous research (Deurenberg et al., 2001) reported that the OMRON BIA device overestimated %BF in females by 0.2 ± 0.2 %BF and underestimated %BF in males by 1.0 ± 0.4 %BF. In a study that included 40 college-age female atheletes, the OMRON BIA device underestimated DXA %BF by an average of -5.11 ± 3.62 %BF (Esco, Olson, Williford, Lizana, & Russell, 2011). In a study of 50

15

college-age males and females, the OMRON BIA device underestimated %BF in men and women by -4.3 ± 9.8 %BF and -8.8 ± 6.2 %BF, respectively (Beam & Szymanski, 2010). In a study of 31 overweight (BMI = 25 to < 30 kg/m^2) women 35–60 years of age, the hand-to-hand OMRON BIA device significantly underestimated fat mass by -2.3 ± 3.3 kg and %BF by -5.6 ± 3.9% (Varady, Santosa, & Jones, 2007). In a group of 110 health men and women between 21 and 60 years of age, the OMRON BIA device underestimated DXA %BF by -6.3 %BF (Lukaski & Siders, 2003).

In this study, estimates of %BF using the OMRON BIA device of only 12% of subjects were within ±4 %BF of the criterion measure (Table 3) and 35% of the estimates underestimated the criterion measure by more than 10 %BF. Our findings are contrary to a previous report that 72% of the estimates of %BF in men and 65% of those in women were within ± 3.5% of the %BF obtained from hydrostatic weighing (Gibson, Heyward, & Mermier, 2000; Norcross & Van Loan, 2004).

Impedance measurements are affected by the water content of the tissue, particularly skeletal muscle tissue. Error in estimates of body composition are introduced by variations in body water due to exercise, weight loss, weight gain, and illness (Mullie, Vansant, Hulens, Clarys, & Degrave, 2008). In this study, we asked subjects to report to the lab in a 3–4 hour fasted state. Although not having a measure of hydration status is a limitation in this study, this and most other studies simulate the likely practical use of hand-to-hand BIA devices in settings in which hydration can only be assumed. Although preassessment directions are provided, there are likely wide discrepancies in how well subjects follow them. The subjects in this study self-reported to be weight stable and not currently trying to lose or gain weight. The large bias in the OMRON BIA device estimates of %BF may also be attributed to the inability of a hand-to-hand

16

BIA device (which essentially measures upper body impendance) to estimate total body %BF (Esco et al., 2011; Varady et al., 2007). It is possible that hand-to-hand BIA underestimates %BF in individuals who have a larger percentage of body fat distributed below the waist.

The magnitude of the overestimate of %BF using the OMRON BIA device increased as %BF increased (Figure 3). This is contrary to the findings of Varady et al. (Varady et al., 2007) who report that the bias between OMRON BIA and the criterion method did not change for different %BF. The greater bias in subjects with greater %BF values may also suggest differences in hydration status or fluid distribution. It is also well undertstood, although perhaps not commonly practiced, that methods and equations to estimate %BF should first be validated in a similar population. Results of this study suggest that the equations used to estimate %BF perform differently as %BF increases, thereby challenging the practice of using the same equation to estimate %BF regardless of body size and body composition.

Estimates of %BF using the OMRON BIA device were highly reliable within and between test administrators (Table 4). The reliability data in this study concurs with that of previous studies. For example, Loenneke et al. (Loenneke et al., 2013) reported that there were no significant differences (0.6 %BF) between measurements of %BF and a high intraclass correlation (ICC) (0.937) on two different days. Previous research (Varady et al., 2007) reported a mean total error (TE) for repeated OMRON BIA estimates of %BF of $0.08 \pm 0.11\%$. Although the results of this study suggest that estimate of %BF using the OMRON BIA device are highly reliable, the large bias and LOA make this device unsuitable for use in the field.

Conclusion

When the bias and LOA between a prediction and a criterion method is large, the prediction method cannot be recommended for assessing the body composition of an individual.

17

Assessing body composition in school, corporate health promotion, or community fitness settings using biased methods undermines the purpose and value of the assessment. The use of methods to assess body composition that tend to underestimate %BF has potential consequences such as prompting concerns over body image and categorizing an overweight individual in a leaner body fat category. The large bias and wide LOAs associated with the the LeanScreen app, manually measured circumferences, and the OMRON BIA device make them poor choices for assessing body composition in normal weight, overweight, and obese adult males and females. Users of the LeanScreen app and the OMRON BIA device should also be aware that the magnitude and direction of the bias depends on the level of body fatness. As this is the first study to evaluate the validity and reliability of estimates of %BF using the LeanScreen app, future research should evaluate %BF with technological advancements. Future research should also evaluate the validity and reliability of %BF assessments when the LeanScreen app is used by test administrators with various levels of experience and expertise, in more subjects with a BMI > 30 kg/m^2 and in subjects who are fully clothed. The ability of the LeanScreen app to effectively track changes in body composition over time resulting from diet and exercise interventions should also be evaluated.

References

Beam, J. R., & Szymanski, D. J. (2010). Validity of 2 skinfold calipers in estimating percent body fat of college-aged men and women. *J Strength Cond Res, 24*(12), 3448–3456.

Bland, J. M., & Altman, D. G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet, 1*(8476), 307–310.

Deurenberg, P., Andreoli, A., Borg, P., Kukkonen-Harjula, K., de Lorenzo, A., van Marken Lichtenbelt, W. D., . . . Vollaard, N. (2001). The validity of predicted body fat percentage from body mass index and from impedance in samples of five European populations. *Eur J Clin Nutr, 55*(11), 973–979.

Esco, M. R., Olson, M. S., Williford, H. N., Lizana, S. N., & Russell, A. R. (2011). The accuracy of hand-to-hand bioelectrical impedance analysis in predicting body composition in college-age female athletes. *J Strength Cond Res, 25*(4), 1040–1045.

Garrow, J. S., & Webster, J. (1985). Quetelet's index (W/H2) as a measure of fatness. *Int J Obes, 9*(2), 147–153.

Gibson, A. L., Heyward, V. H., & Mermier, C. M. (2000). Predictive accuracy of Omron body logic analyzer in estimating relative body fat of adults. *Int J Sport Nutr Exerc Metab, 10*(2), 216–227.

Heyward, V., Wagner, H., & Dale R. (2004). *Applied Body Composition Assessment 2nd edition*. Champaign, IL: Human Kinetics.

Hodgdon, J. A., & Friedl, K. (1999). *Development of the DoD body composition estimation equations*. (99–2B). San Diego, CA.

Loenneke, J. P., Barnes, J. T., Wilson, J. M., Lowery, R. P., Isaacs, M. N., & Pujol, T. J. (2013). Reliability of field methods for estimating body fat. *Clin Physiol Funct Imaging, 33*(5), 405–408.

Lukaski, H. C., & Siders, W. A. (2003). Validity and accuracy of regional bioelectrical impedance devices to determine whole-body fatness. *Nutrition, 19*(10), 851–857.

Mullie, P., Vansant, G., Hulens, M., Clarys, P., & Degrave, E. (2008). Evaluation of body fat estimated from body mass index and impedance in Belgian male military candidates: comparing two methods for estimating body composition. *Mil Med, 173*(3), 266–270.

National Institute of Health. (1998.). *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults*. 98–4083.

Norcross, J., & Van Loan, M. D. (2004). Validation of fan beam dual energy x ray absorptiometry for body composition assessment in adults aged 18-45 years. *Br J Sports Med, 38*(4), 472–476.

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2013). Prevalence of obesity among adults: United States, 2011-2012. *NCHS Data Brief* (131), 1–8.

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the united states, 2011-2012. *JAMA, 311*(8), 806–814.

Posture Co Inc. (2014). LeanScreen App Body Fat BMI BMR Waist to Hip Ratio. The Fat Analysis Photo Finish. Retrieved from http://postureanalysis.com/leanscreen-app-body-fat-bmi-bmr-waist-to-hip-ratio/.

Schuna J.M., Hilgers-Greterman S.J., Manikowske T.L., Tucker J.M., & Liguori G. (2013). Evaluation of Circumference-based Prediction Equation to Assess Body Composition Changes in Men. *Int J Exerc Sci, 6*(3), 188–198.

US Department of Defense. (2013). *The Army Body Composition Program*. (Army Regulation 600–9). Washington DC.

Varady, K. A., Santosa, S., & Jones, P. J. (2007). Validation of hand-held bioelectrical impedance analysis with magnetic resonance imaging for the assessment of body composition in overweight women. *Am J Hum Biol, 19*(3), 429–433.

Weaver, A. M., Hill, A. C., Andreacci, J. L., & Dixon, C. B. (2009). Evaluation of Hand-to-Hand Bioelectrical Impedance Analysis for Estimating Percent Body Fat in Young Adults. *Int J Exerc Sci, 2*(4), 254–263.

Table 1 Participant Characteristics

	Normal BMI (18.5–25 kg/m^2)		Overweight BMI (25–30 kg/m^2)		Obese BMI (30–35 kg/m^2)		
	Male (n = 31)	Female (n = 30)	Male (n = 32)	Female (n = 28)	Male (n = 19)	Female (n = 8)	Combined (n = 148)
Age (years)	23.5 ± 3.1	21.7 ± 4.1	5.4 ± 6.3	23.5 ± 4.9	26.4 ± 6.6	28.5 ± 9.1	24.02 ± 5.5
Height (m)	1.81 ± 0.05	1.66 ± 0.5*	1.78 ± 0.06	1.66 ± 0.05*	1.79 ± 0.07	1.69 ± 0.03*	1.74 ± 0.09
Body Mass (kg)	73.8 ± 6.6	60.9 ± 5.7*	86.6 ± 8.8	73.6 ± 6.4*	102.6 ± 9.5	90.9 ± 4.6*	78.56 ± 14.9
BMI (kg/m2)	22.5 ± 1.7	22.1 ± 1.6	27.3 ± 1.6	26.8 ± 1.36	32.0 ± 1.5	31.7 ± 1.1	26.0 ± 3.8
Neck (cm)	15.0 ± 0.8	12.9 ± 0.5*	15.8 ± 0.79	13.7 ± 0.67*	16.8 ± 1.0	14.5 ± 1.0*	14.7 ± 1.5
Abdomen (cm)	32.5 ± 2.1	30.8 ± 2.3*	36.2 ± 2.8	35.1 ± 2.1	42.4 ± 3.2	42.2 ± 2.7	35.3 ± 4.6
Waist (cm)	31.2 ± 1.7	27.9 ± 1.5	34.8 ± 2.5	31.5 ± 1.8*	39.9 ± 2.7	37.3 ± 1.6	32.8 ± 4.3
Hips (cm)	37.9 ± 1.8	37.8 ± 1.6	40.6 ± 1.9	41.3 ± 1.9	43.7 ± 1.8	45.4 ± 2.0	40.2 ± 3.0
WHR	0.82 ± 0.03	0.74 ± 0.03	0.86 ± 0.05	0.76 ± 0.03*	0.91 ± 0.05	0.82 ± 0.05*	0.81 ± 0.07
%BF	18.4 ± 5.9	29.7 ± 3.9*	24.4 ± 5.5	36.7 ± 3.9*	33.3 ± 6.3	43.9 ± 4.7*	28.8 ± 8.9

All values are mean ± SD.

Neck, abdomen, waist, and hips represent circumferences.

WHR = waist-to-hip ratio. BMI = body mass index. %BF = percent body fat from DXA.

* = Gender differences ($p < 0.05$) in variable within BMI category.

Table 2 Estimates of Percent Body Fat

	Male	Female	Combined		
	(n = 82)	(n = 66)	(n = 148)	Bias	Limits of Agreement
DXA	24.2 ± 8.1	34.4 ± 6.2	28.8 ± 8.9		
LeanScreen™	21.1 ± 6.5	32.0 ± 7.0	26.0 ± 8.6	−3.26 ± 3.57*	± 6.99 (−10.26 – 3.73)
Circumference	18.6 ± 7.0	29.9 ± 6.8	23.7 ± 8.9	−4.82 ± 3.45*	± 6.76 (−11.58 – 1.94)
OMRON	16.0 ± 6.5	25.7 ± 5.3	20.3 ± 7.7	−8.45 ± 3.48*	± 6.82 (−15.3 – −1.63)

All values are mean ± SD.

Bias is the average difference between prediction method and DXA.

Limits of Agreement (LOA) are 1.96 x SD of bias.

* = Bias between prediction method and DXA is significantly different from zero.

Table 3 Percentage of Estimates of Percent Body Fat Falling Within Various Ranges of the
Criterion Measure

%BF	LeanScreen[TM]	Circumferences	OMRON
± 1	18%	8%	2%
± 2	16%	12%	2%
± 4	26%	21%	8%
± 6	19%	20%	11%
± 8	9%	20%	17%
± 10	9%	15%	25%
± >10	3%	4%	35%
Mean	−3.26	−4.82	−8.45

Mean = Average difference (bias) between estimates of %BF using the LeanScreen[TM] app,
circumferences, OMRON and DXA.

23

Table 4 Sources of Variance of Estimates of Percent Body Fat

	LeanScreen^{TM}	Circumference	OMRON
Subject	69.40	78.83	56.11
Rater	0.605	0.13	< 0.001
Trial	< 0.001	0.0037	0.010
Rerated	0.02	—	—
Error	0.87	0.35	0.11

Rerated refers to the administrator who rated their first set of photographs on day one and again

on day two.
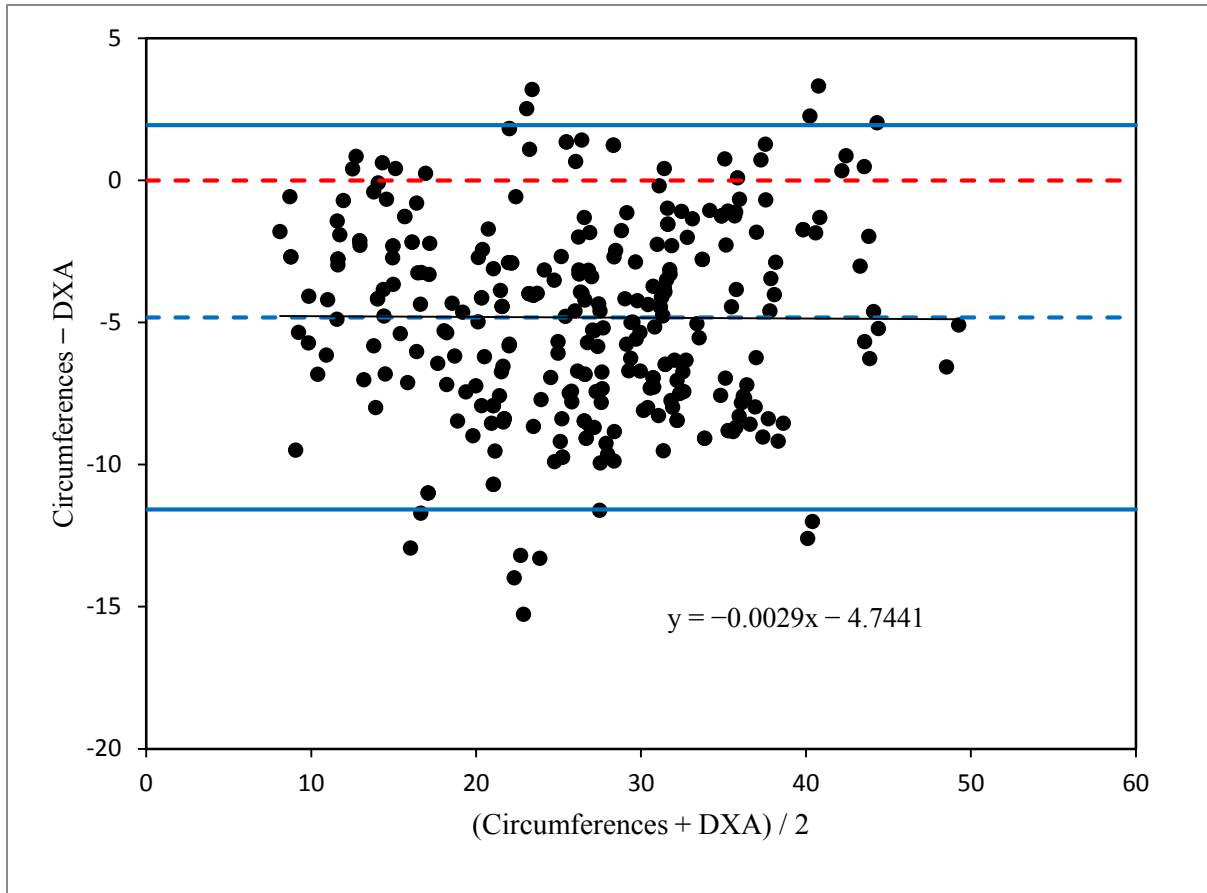
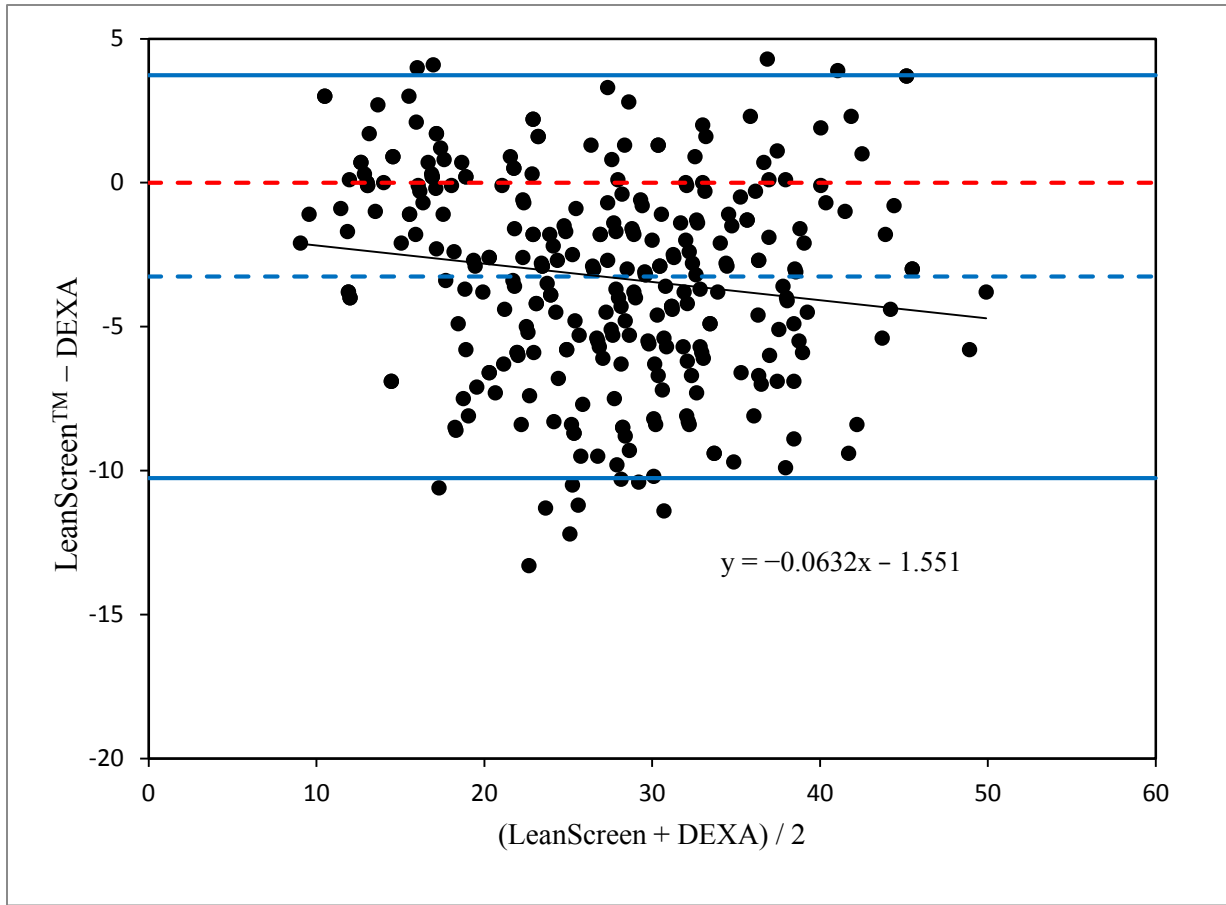Figure 1 Bland-Altman Plot of %BF for DXA and Circumference Measurements

Figure 2 Bland-Altman Plot of %BF for DXA and LeanScreen™

The plot shows the equation: $y = -0.0632x - 1.551$

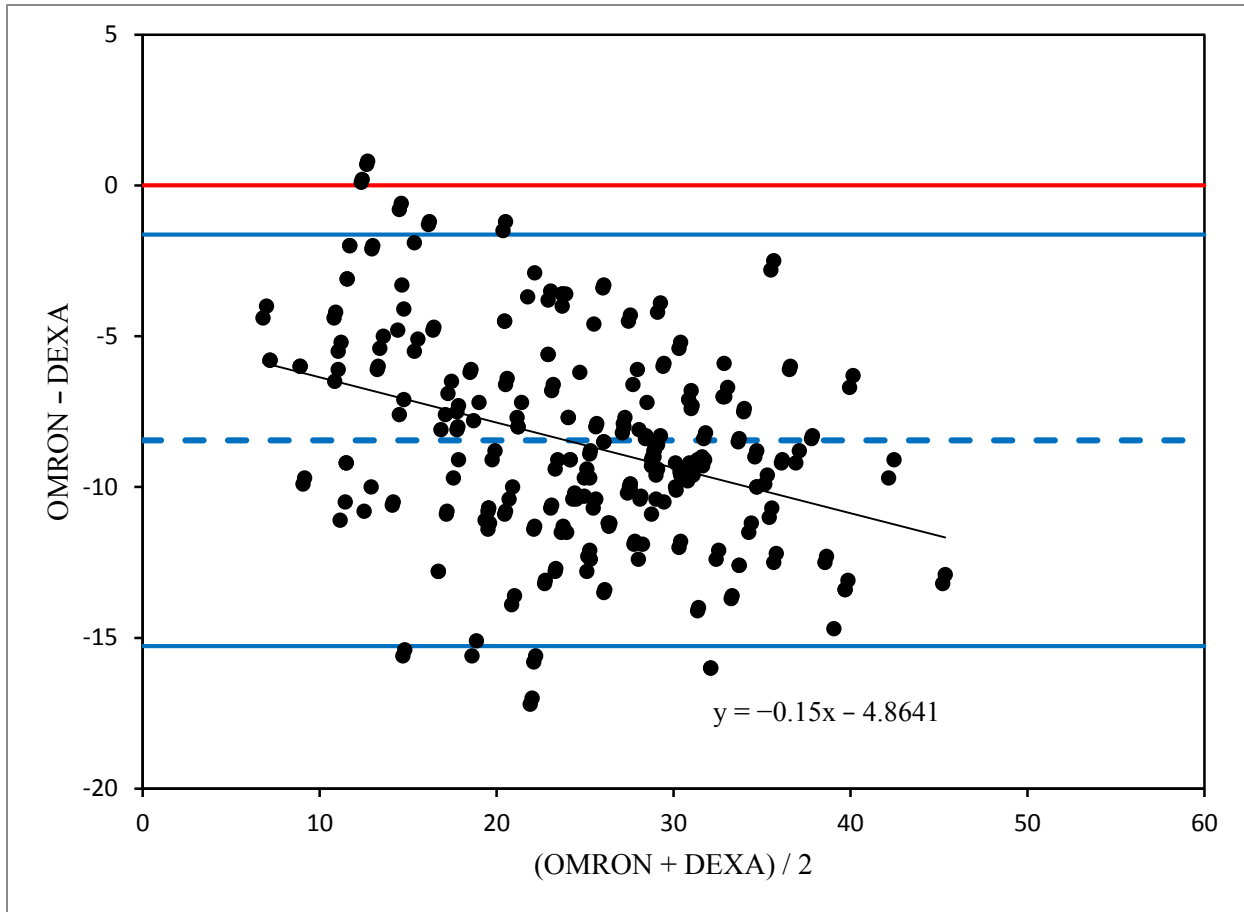The axes are labeled: y-axis "LeanScreen™ – DEXA" and x-axis "(LeanScreen + DEXA) / 2"

Figure 3 Bland-Altman Plot of %BF for DXA and OMRON

The plot shows the equation: $y = -0.15x - 4.8641$