UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

THE ABILITY OF THE LEANSCREEN TO ACCURATELY ASSESS WAIST-TO-HIP RATIO AND PERCENT BODY FAT IN COMPARISON TO LABORATORY TESTED PROCEDURES

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College of Science and Health
Clinical Exercise Physiology

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THE ABILITY OF THE LEANSCREEN TO ACCURATELY ASSESS WAIST-TO-HIP RATIO AND PERCENT BODY FAT IN COMPARISON TO LABORATORY TESTED PROCEDURES

By Raymond Marx

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology.

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ABSTRACT

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Waist-to-hip ratio (WHR) and percent body fat (%BF) are commonly used in wellness and clinical settings, and while there is only one commonly used method for measuring WHR, %BF can be determined in many ways. However, the accuracy, reliability, and cost of these many methods of calculating %BF vary greatly. The purpose of this study was to assess the accuracy of the LeanScreen's ability to measure WHR and %BF against laboratory validated methods. Eighty subjects participated in this study. Waist-to-hip ratio was manually measured and %BF was determined by the BOD POD. Two photographs were taken of the subjects with the LeanScreen app according to the procedures demonstrated by the app. No significant difference (p=0.554) was found for WHR between the LeanScreen app and manual WHR measurements, and 73 subjects (91%) were within one standard deviation (0.08) of the mean. A significant difference (p=0.015) was found between %BF determined by the LeanScreen app and the BOD POD. Although a high correlation exists between the two methods (r=.82), only 35 subjects were within ± 3% of the BOD POD (SEE=5.1). In conclusion, the LeanScreen app accurately determines WHR but does not accurately determine %BF on an individual basis.

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INTRODUCTION

Body composition is an important component of health-related fitness because of the relationship between excess body fat and chronic disease. Individuals classified as overweight or obese have a higher risk of developing a variety of diseases, including Type 2 diabetes, cardiovascular disease, and stroke (National Institute of Diabetes and Digestive and Kidney Diseases, 2012). Epidemiologically, the degree of overweight or obesity are often classified by body mass index (BMI) or waist-to-hip-ratio (WHR) because both methods are fast and easy to determine (Kavak, Pilmane, Kazoka, 2011). Body mass index is calculated by dividing a person's weight in kilograms by the square of their height in centimeters, and WHR is determined by dividing the circumference of a person's waist at the narrowest part (usually at the umbilicus) by the circumference of their hips at the widest part (Cheatham, 2013). There are a variety of other ways to measure body composition including skinfold measurements, bioelectrical impedance analysis, hydrostatic weighing, bone density scanning, and the use of a BOD POD (Life Measurement Inc., Concord, CA), but the accuracy, ease of use, and cost of using these methods can vary greatly. Personal trainers, nutritionists, physicians, and other professionals who use these methods to determine if a patient or client should gain or lose weight would benefit from and inexpensive, accurate, and simple way of measuring body composition.

PostureCo (PostureCo, Trinity, FL) is a software company that has developed an app for a phone or tablet that uses photographs to assess a person's percent body fat

(%BF), BMI, and WHR, among a few other measurements. PostureCo's LeanScreen app incorporates photographs taken from the front and side to measure a subject's %BF, BMI, and WHR. According to PostureCo's website, the LeanScreen app can predict these measurements to within 3% accuracy (Ferrantelli, 2016). To our knowledge, the accuracy of the LeanScreen app has never been independently tested and validated. The purpose of this study was to assess the accuracy of the LeanScreen app by testing it against laboratory validated methods.

MATERIALS AND METHODS

Subjects

The subjects for this study were 40 male and 40 female volunteers, with a diverse set of body types and ages. This allowed for a determination of the accuracy of the LeanScreen app across a wide range of people and to determine if the app is reliable at determining WHR and %BF. The purpose and procedure of this study was explained to each subject prior to testing. Each subject provided written informed consent prior to undergoing any testing procedures. The study was approved by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects.

Experimental Design

Each subject was measured for WHR and %BF. Height and weight were measured using a mechanical scale (Pellstar L.L.C. Health O Meter, McCook, IL). Height was measured in meters to two decimal points and weight was measured to the nearest kilogram with one decimal point. Waist-to-hip-ratio was determined by dividing the circumference of the subject’s waist at the narrowest part by the circumference of their hips at the widest part as recommended by the American College of Sports Medicine (ACSM) (Cheatham, 2013). Waist-to-hip ratio measurements were made to the nearest centimeter using a tape measure. The subject stood tall with his or her hands to the side. The waist measurement was made at the narrowest part of the waist, just above the iliac crest. The subject stood with their feet shoulder width apart, exhaled completely, and the tape was wrapped around their body at a level angle to ensure proper measurement. The tape was snug to the waist to ensure accurate measurements, but was not tight to the point of moving or displacing the skin. Hip measurements were made in the same manner except they were taken at the widest part of the hips. Percent body fat was measured to one decimal point using a BOD POD, which measures the amount of air displaced by a person in a known volume of space. Although hydrostatic weighing has been considered the gold standard for measuring %BF (Biaggi et al. 1999), research by Vescovi et al. (2001), McCrory et al. (1995), Fields et al. (2000), Field, Hunter and Goran (2000), Nunez et al. (1999) have shown the BOD POD to be virtually identical to hydrostatic weighing as a means of measuring %BF.

Pictures of each subject were taken using the LeanScreen app on an iPad (Apple Inc., Cupertino, CA) following the procedures provided by PostureCo Inc. Two photographs were taken from twelve feet away for consistency, one from the front and the other from the side. Reference lines were drawn onto the photos in the software program according to the directions given by the LeanScreen app. Using the photograph from the front-view, reference points were placed at each side of the neck, halfway between the sternum and umbilicus, at the level of the umbilicus, and at each side of the hips at the widest location. Reference points from the side-angle photograph were placed according to the same locations as the front-view photograph. The subject’s height, weight, age, and gender also were entered into the software program.

Results were compared to measurements recorded using reference methods to determine the accuracy of the LeanScreen app in predicting WHR and %BF. For all measurements, each participant wore tight-fitting clothing (swimsuit or spandex and a sports bra) and a swim cap. The reason for this is two-fold: tight clothing allows for more accurate placement of reference points on the LeanScreen app, and a swim cap minimizes heat lost from the head during the BOD POD measurements.

STATISTICAL ANALYSIS

Standard descriptive statistics were used to determine the baseline characteristics of the subjects. Paired-samples t-tests were used to compare differences in %BF determined by the BOD POD and the LeanScreen app, and WHR determined by manual circumference measurements compared to the LeanScreen app. Pearson product-moment correlations were used to compare the relationship between BOD POD and LeanScreen body fat values, and WHR determined by the LeanScreen app and manual measurement. Standard error of the estimate (SEE) were determined using linear regression analysis. All data were analyzed using the Statistical Package for the Social Services (SPSS Inc., Chicago, IL). Alpha was set at .05 to achieve statistical significance.

RESULTS

Eighty subjects were used in this study, of which 40 were male and 40 female.ff Descriptive statistics of the 80 subjects are presented in Table 1.

Table 1. Descriptive characteristics of subjects (N=80).

	Female (n=40)	**Male (n=40)**
Age (yrs.)	35.3 ± 11.78	29.2 ± 12.89
Height (m)	1.66 ± 0.066	1.79 ± .073
Weight (kg)	68.3 ± 10.94	82.8 ± 14.70

Data are reported as mean ± standard deviation.

Percent Body Fat

Overall, %BF was signifcantly underpredicted by the LeanScreen app compared to the BOD POD (20.2 ± 7.74 vs. 21.6 ± 8.77). A plot of the data are presented in Figure 1. The correlation between the LeanScreen and BOD POD %BF was r=.82 and the SEE was 5.1.

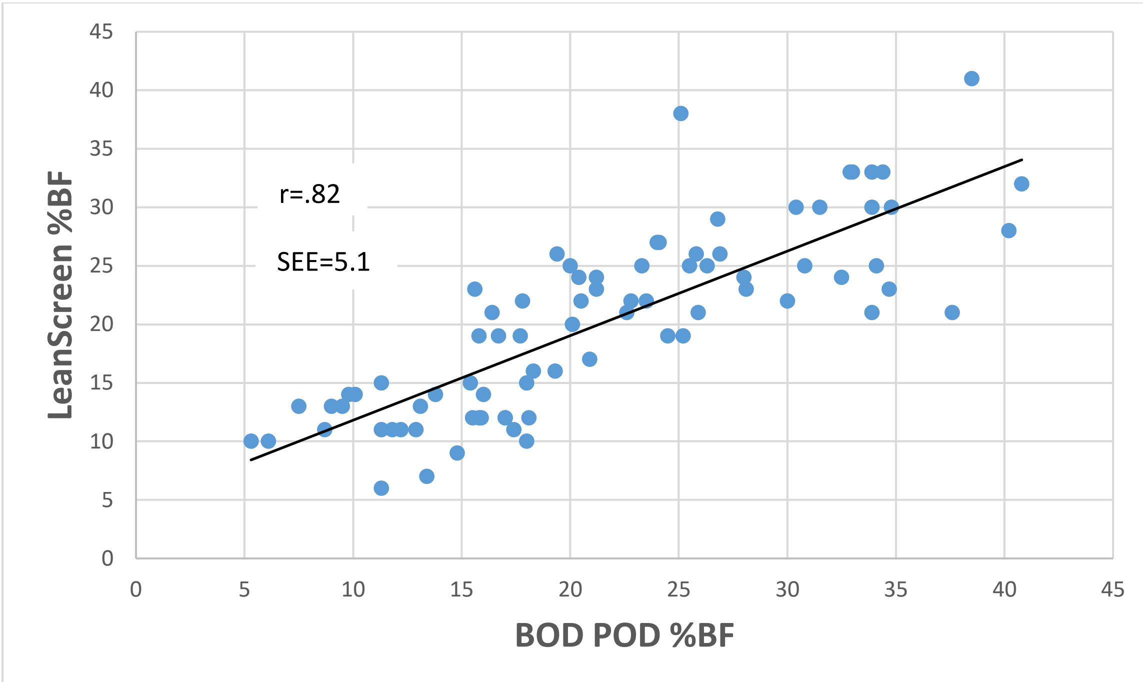

Figure 1. Relationship between percent body fat (%BF) determined by the BOD POD and the LeanScreen app.

Upon examination of the calculated differences seen in Figure 2, it was noted that people with a lower percent body fat (<10%) were overpredicted by the LeanScreen app, and people with a higher percent body fat (>30%) were underpredicted by the LeanScreen app. Thus, subjects were divided into three groups based on %BF as calculated by the BOD POD and means were compared for subjects with a %BF of <10%, 10%-30%, and >30%. It was found that for subjects with a %BF <10%, LeanScreen significantly overpredicted %BF by an average of 4% (12.0 ± 1.63 vs. 8.0 ± 1.74). For subjects between 10%-30% body fat, there was no significant difference between the LeanScreen and BOD POD (18.5 ± 6.52 vs. 19.3 ± 5.12). In subjects with %BF >30%, LeanScreen significantly underpredicted %BF by an average of 5.7% (28.9 ± 5.26 vs. 34.6 ± 3.03).

The LeanScreen app claims to be accurate within 3 percent of actual %BF. Of the 80 subjects, only 35 (44%) had a %BF as predicted by LeanScreen that was within ± 3% of BOD POD values. A plot of the differences between %BF determined by the BOD POD and LeanScreen is presented in Figure 2.

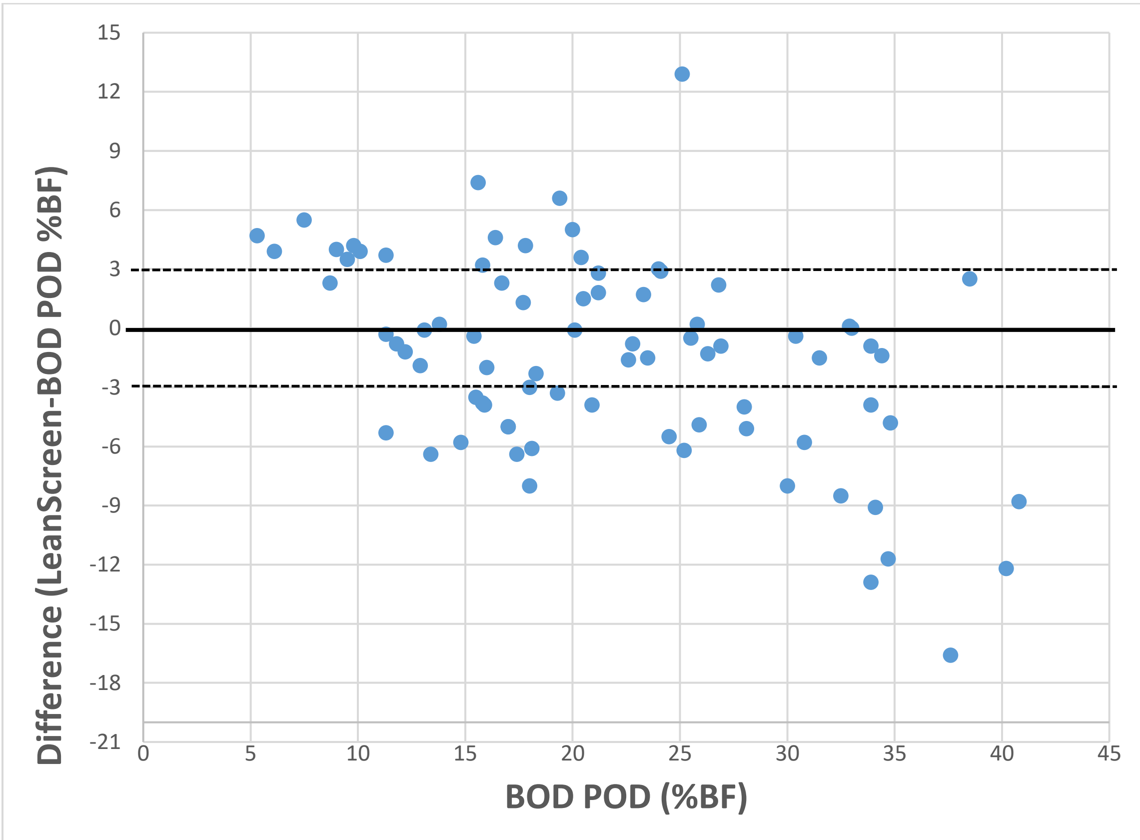

Figure 2. Difference between percent body fat (%BF) determined by the BOD POD and the LeanScreen app. Dotted lines represent ± 3% difference between the LeanScreen app and the BOD POD.

Waist-to-Hip Ratio

Overall, there was no significant difference in WHR as determined by the LeanScreen app compared to manually measured values. The correlation between the LeanScreen app and manual measurement values was r=.83 and the SEE was 0.04. Because LeanScreen rounds to only one decimal point when determining WHR, data are shown in straight lines on the vertical (y) axis, whereas manually measured WHR values were reported to two decimal points on the horizontal (x) axis. A plot of the data is presented in Figure 3.

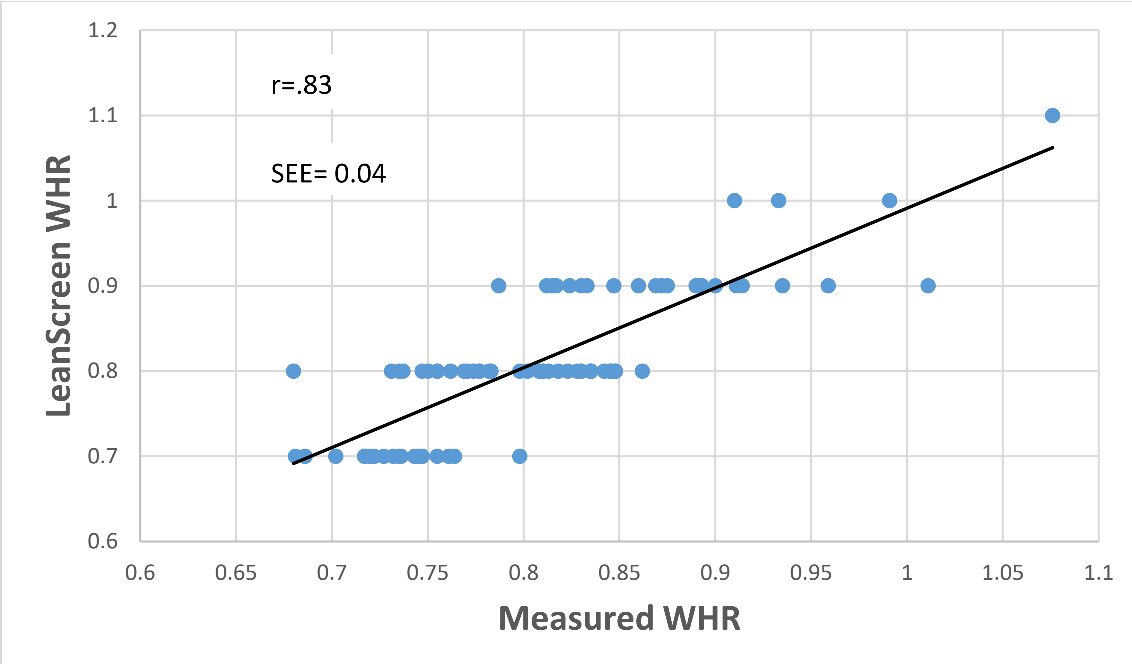

Figure 3. Relationship between manually measured waist-to-hip ratio (WHR) and WHR determined by the LeanScreen app.

Differences between WHR as determined by the LeanScreen app compared to manually measured WHR values are presented in Figure 4. The horizontal lines represent one standard deviation above and below the line of identity. Upon examination of the graph, 73 (91%) subjects fell within one standard deviation (0.08) of the line of identity.

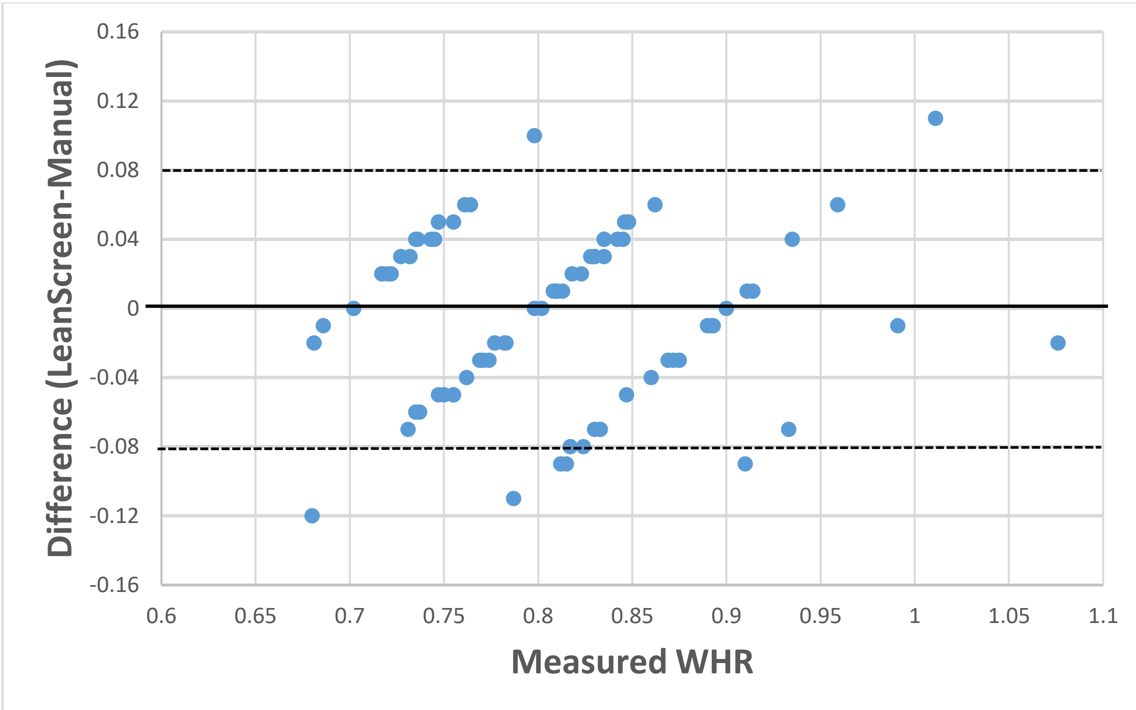

Figure 4. Relationship between measured waist-to-hip ratio (WHR) value and the difference between measured WHR and LeanScreen-predicted WHR. Dotted lines represent ± 1.96 SEE units.

DISCUSSION

The purpose of this study was to determine to accuracy of the LeanScreen app to accurately assess %BF and WHR by comparing these values to %BF measured by the BOD POD and a manual WHR measurement. The findings indicate that although the mean difference between the BOD POD and LeanScreen in relation to %BF was only 1.4% (21.6% vs. 20.2%), there was a wide variation in accuracy, depending upon the actual %BF of the individual. A review of the plot of residuals showed that the LeanScreen app significantly overpredicted %BF by an average of 4.0% for subjects who were less than 10% body fat according to the BOD POD, and significantly underpredicted %BF by an average of 5.7% for subjects above 30% body fat. Although there was a high correlation between the BOD POD and LeanScreen app (r=.82), there was a high degree of variability (SEE= 5.1) and only 44% of subjects were within ± 3% of BOD POD %BF. PostureCo Inc. (PostureCo, Trinity, FL), the maker of the LeanScreen app, reports the accuracy to be within ± 3% of the hydrostatic weighing method of determining %BF. Hydrostatic weighing (HW) is considered the "gold standard" for determining body composition (Biaggi et al. 1999). However, numerous studies have found that the BOD POD results in virtually identical %BF values compared to HW, with correlations ranging from r=.90-.97 (Vescovi et al. (2001), McCrory et al. (1995), Fields et al. (2000), Field, Hunter and Goran (2000), Nunez et al. (1999)).

The high SEE value of 5.1 found in the study is higher than most other common methods for measuring %BF, such as skinfold measurements, dual-energy X-Ray absorptiometry (DEXA), the 3-compartment model, and bioelectrical impedance analysis (BIA). Vescovi et al. (2001) and Dixon, Deitrick, Pierce, Cutrufello, and Drapeau (2005) reported the SEE between HW and the BOD POD to be very low at 1.81 and 1.68, respectively. Bentzur, Kravitz, and Lockner (2008) and Dixon et al. (2005) found the SEE of skinfold assessments to be 2.05 compared to the BOD POD and 1.87 compared to HW, respectively. Maddalozzo, Cardinal, and Snow (2003) reported an SEE of 0.8 comparing DEXA to the BOD POD. Moon et al. (2008) found an SEE of 2.42 while comparing the 3-compartment model to the BOD POD. Although a review of literature showed no studies reporting an SEE comparing BIA to the BOD POD, Dixon et al. (2005) reported an SEE of 3.60 comparing the BOD POD to HW.

In respect to WHR, no significant difference was found between manually measured WHR values and those reported by the LeanScreen app, and there was a high correlation (r=.83) and low SEE (0.04) between the two methods. A plot of the residuals revealed an equal distribution of data around the line of identity. In total, 73 of the 80 subjects (91%) had values predicted by the LeanScreen app that were within 1.96 SEE units (0.08) of manually measured WHR values, indicating highly accurate measurements by the LeanScreen app. A problem with the LeanScreen app is that the software only rounds to the nearest one decimal point (e.g.; 0.7, 0.8, 0.9). Most guidelines for WHR are carried out to two decimal points. For instance, the ACSM states that a WHR above 0.95 for men and 0.86 for women correlates to a higher risk of chronic disease (Pescatello et al. 2014). Because the LeanScreen app only rounds to one decimal point, some people may be misclassified due to what their WHR value is and what it is rounded to.

CONCLUSION

Although overall %BF values were similar between the BOD POD and the LeanScreen app, there was considerable variability, especially for individuals with low and high %BF values. Additionally, only 44% of subjects were within ± 3% as reported by PostureCo Inc. and the SEE was 5.1 %BF, which is higher than most methods for predicting body composition. The LeanScreen app accurately predicts WHR, although because the software only rounds to one decimal point, a small amount of people may be misclassified due to rounding error.

REFERENCES

Bentzur, K., Kravitz, L., Lockner, D. (2008). Evaluationn of the BOD POD for estimating percent body fat in collegiate track and field female athletes: a comparison of four methods. *Journal of strength and conditioning research*. 22(6). 1985-1991. DOI: 10.1519/JSC.0b013e318185f195

Biaggi, R., Vollman, M., Niew, M., Brener, C., Flakoll, P., Levenhagen, D., Sun, M., Karabulut, Z., Chen, K. (1999). Comparison of air-displacement plethysmography with hydrostatic weighing and bioelectrical impedance analysis for the assessment of body composition in healthy adults. *American Journal of Clinical Nutrition*. 69. 898-903.

Cheatham, M. 2013. *Section 6: Body Composition* [PowePoint Slides]. Retrieved from: http://homepages.wmich.edu/~ccheatha/hphe4450/files/handouts/Section06-Body%20Composition-Handouts.pdf

Dixon, C., Ronald, D., Pierce, J., Cutrufello, P., Drapeau, L. (2005). Ecaluation of the BOD POD and leg-to-leg bioelectrical impedance analysis for estimating percent body fat in national collegiate athletic association division III collegiate wrestlers. National Strength and Conditioning Association. 19(1). 85-91.

Ferrantelli, J. (2016). LeanScreen app for body fat analysis and waist hip ratio-how does it work?. [Video file].Retrieved from postureanalysis.com/leanscreen-app-body-fat-bmi-bmr-waist-to-hip-ratio/

Fields, D., Hunter, G., Goran, M. (2000). Validation of the BOD POD with hydrostatic weighing: Influence of body clothing. International Journal of Obesity and Related Metabolic Disorders. 24(2) 200-205.

Fields, D., Wilson, D., Gladden, B., Hunter, G., Pascoe, D. Goran, M. (2000). Comparison of the BOD POD with the four-compartment model in adult females. Medicine and science in sports and exercise. 1605-1610.

Kavak, V., Pilmane, M., Kazoka, D. (2011). Body mass index, waist circumference and waist-to-hip ratio in the prediction of obesity in Turkish teenagers. *Collegium Antropologicum*. 38(2) 445-451.

Maddalozzo, G., Cardinal, B., Snow, C. (2003). Concurrent validity of the BOD POD and Dual Energy X-Ray absorptiometry techniques for assessing body composition in young women. *Journal of the American Dietetic Association*. 102 (11) 1677-1679.

McCrory, M., Gomez, T., Bernauer, E., Mole, P. (1995). Evaluation of a new air displacement plethysmograph for measuring human body composition. *Medicine and Science in Sports and Exercise*. 27(12), 1686-1691.

Moon, J., Tobkin, S., Smith, A., Roberts, M., Ryan, E., Dalbo, V., Lockwood, C. Walter, A., Cramer, J., Beck, T., Stout, J. (2008). Percent body fat estimations in college men using field and laboratory methods: A three-compartment model approach. Dynamic Medicine. 7(7). DOI: 10.1186/1476-5918-7-7

National Institute of Diabetes and Digestive and Kidney Diseases. (2012, December). Health risks of being overweight. Retrieved from https://www.niddk.nih.gov/health-information/health-topics/weight-control/health_risks_being_overweight/Pages/health-risks-being-overweight.aspx

Nunez, C., Kovera, A., Pietrobelli, A., Heshka, S., Horlick, M., Kehayias, J., Wang, Z., Heymsfield, S. (1999). Body composition in children and adults by air displacement plethysmography. European Journal of Clinical Nutrition. 53. 382-387.

Pescatello, L., Arena, R., Riebe, D., Thompson, P. (2014). *ACSM's guidelines for exercise testing and prescription*. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health.

Vescovi, J., Zimmerman, S., Miller, W., Hildebrandt, L., Hammer, R., Fernhall, B. (2001). Evaulation of the BOD POD for estimating percentage body fat in a heterogeneous group of adult humans. *European journal of applied physiology*. 85. 326-332. DOI: 10.1007/s004210100459

APPENDIX A

INFORMED CONSENT

Protocol Title: The ability of LeanScreen to accurately assess %BF and WHR against laboratory tested methods

Principal Investigator: Ray Marx
930 Copeland Ave. Apt #: 109
La Crosse, WI 54603
Phone #: (608) 738-6446

Purpose and Procedure

- The purpose of this study is to determine the accuracy of PostureCo's application Lean Screen to assess body composition, BMI, and WHR
- My participation will involve having my height and weight recorded to determine BMI, as well as being measured around the hips and waist to determine WHR. I will also have my body composition analyzed inside a BOD POD by following procedures accompanying BOD POD. Finally, I will also have pictures taken from multiple angles using the Lean Screen app to determine the accuracy compared to measured values.
- The total time requirement is one hour during just one session.
- Testing will take place in 225 Mitchell Hall, UW-L.
- During testing, I will wear tight fitting, spandex clothing to most accurately measure body composition while in the BOD POD and for analysis of photographs taken in the Lean Screen application. I will also wear a swim cap during the time spent in the BOD POD

Potential Risks

- I may experience some claustrophobia while sitting in BOD POD due to small, enclosed space.
- Individuals trained in CPR, Advanced Cardiac Life Support, and First Aid will be in the laboratory during time of testing, and testing will be terminated if complications occur.
- The risk of serious complications or injury is near zero.

Rights and Confidentiality

- My participation is voluntary and I can withdraw or refuse to answer any question without consequences at any time.
- I can withdraw from the study at any time for any reason without penalty.
- The results of this study may be published in scientific literature or presented at professional meetings using grouped data only.
- All information will be kept confidential through the use of number codes. My data will not be linked with personally identifiable information.

Possible Benefits

- I and other participants may benefit by learning my weight measurement classification and correlated risk status.
- Questions regarding study procedures may be directed to Ray Marx (608-738-6446), the principal investigator, or the study advisor Dr. John Porcari, Department of Exercise and Sport Science, UW-L (608-386-5416). Questions regarding the protection of human subjects may be addressed to UW-La Crosse Institutional Review Board for the Protection of Human Subjects, (608-785-8124 or irb@uwlax.edu).

Participant____________________________________ Date________________

Researcher____________________________________ Date________________

Narrative Statement

1. The purpose of this study will be to determine the accuracy of PostureCo's Lean Screen application that is used to assess body composition, body mass index (BMI), waist-to-hip ratio (WHR), lean body mass, and fat mass. Each subject will be measured for BMI by measuring their height and weight. WHR is calculated using circumference measurements around the waist and hip, and body composition will be measured using a BOD POD, where subjects sit in a capsule and the volume of displaced air is measured. These values will be compared to pictures taken of the subject using the application on an iPhone or tablet.
2. Subjects will be 60-80 male and female volunteers of various ages and body sizes. The reason for using both men and women of different ages and sizes is to determine the accuracy of the Lean Screen application for different populations. This study will begin in November, 2017, and conclude in May, 2017.
3. Not applicable
4. Voluntary written informed consent will be obtained from each subject prior to testing. Subjects will have the study explained to them and given the opportunity to ask questions.
5. Subject names will not be included on any material that references the measurements recorded or in the pictures taken. Also, pictures of the subjects will be deleted following the assessment of the accuracy of the application to ensure confidentiality. In the event of presentation or publication of the results of this study, only aggregate data will be presented.
6. Each subject will be required to spend approximately one hour in the laboratory to obtain all required measurements. There is virtually no risk involved with the testing, however subjects will be required to be in a small, enclosed capsule (BOD POD), which could provoke claustrophobic symptoms in some subjects.
7. Although the risk potential for this study is low, each subject will have all procedures explained thoroughly to them. This is especially important when being tested in the BOD POD, because of it being a small, enclosed space. Individuals trained in CPR and Advanced Cardiac Life Support will be conducting all testing, and an AED is available in the laboratory where testing will take place.
8. Subjects who participate in this study will learn their BMI, WHR, and body composition. This will be helpful for them as they will learn whether they are at a safe, healthy weight classification. The public will gain information about the accuracy of the Lean Screen application after the conclusion of this study.

APPENDIX B

REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

Obesity rates in the United States are at an all-time high and have been increasing rapidly for the last few decades. According to the Centers of Disease Control and Prevention (Centers for Disease Control, 2015), one-third of adults in the United States are obese. According to the National Institute of Diabetes and Digestive Disorders (National Institute of Diabetes and Digestive and Kidney Diseases, 2012), obese people have a higher risk of developing a variety of diseases including Type 2 diabetes, cardiovascular disease (CVD), and stroke. Weight classifications (underweight, normal, obese (I,II,III)) are determined by measurement tools such as body mass index (BMI), hip-to-waist ratio (WHR), and body composition analysis or percent body fat (%BF). Although %BF is the preferred form of measurement, BMI and WHR are most commonly used because they are more economically feasible and easier to measure (Kavak, Pilmane, Kazoka, 2011). The purpose of this paper is to review the literature of the uses and accuracy of these measurement methods and why they are important markers in weight related health factors.

Body Mass Index

Body mass index is a tool used for measuring body fat by dividing a person's weight in kilograms (kg) by the square of their height in centimeters (cm) (Cheatham, 2013). The American College of Sports Medicine (ACSM) states that health problems associated with obesity generally increase above a BMI of 25.0, and that higher mortality rates are associated with a BMI of 30.0 or higher (Cheatham, 2013). BMI is often used in clinical and fitness settings because it is simple to measure, economically feasible, and non- invasive (Han, Ko, Cho, 2012). Although this is a common and widely accepted means of determining body fat analysis, BMI is not the ideal form of classifying a person's obesity status because the method cannot account for lean body mass as opposed to fat mass (Lam et al. (2015). This can often lead to an over classification of lean, fit individuals as overweight simply because of the volume of muscle adding to their overall weight (Han et al. (2012). Finally, BMI cannot account for the location of adipose tissue on each individual, which can have negative health effects because of the higher risk of health complications associated with high visceral fat levels in comparison to overall adipose tissue distribution (Lam, et al. 2015).

Waist to Hip Ratio

Waist to hip ratio is another method for measuring a person's body fat, specifically abdominal fat, and is found by measuring the circumference of a person's waist at the narrowest part of the abdomen, usually just above the iliac crest, and dividing that by the measure of a person's hips which is taken at the widest circumference (Pescatello, Arena, Riebe, and Thompson (2014). Like BMI, a person's WHR can be used as a risk assessment marker for determining if a person is at an elevated risk for CVD or other chronic illnesses. According to ACSM, WHR is an effective and reliable method for identifying persons with an elevated risk of chronic disease, and ACSM states that a WHR above 0.95 for young men and 0.86 for young women correlates to a higher risk of chronic disease (Pescatello et al. 2014).

Body Composition

Although BMI and WHR are commonly used for determining the weight classification of an individual and subsequent health risk factor, body composition is the preferred method of choice because of its accuracy and because it offers a more complete assessment of the amount of fat tissue, muscle mass, bone density, and water. According to Wagner and Heyward (1999), body composition has been linked to various chronic diseases such as CVD, diabetes, osteoporosis, and some cancers. Although an exact ideal %BF for men and women is not currently defined, a range of 10-22% for men and 20-32% for women is viewed as satisfactory for health (Lohman, 1982). There are many methods for measuring %BF, including hydrostatic weighing (HW), air displacement plethysmography (ADP), bioelectrical impedance analysis (BIA), skinfold measurements, four-component model, dual-energy X-Ray absorptiometry (DEXA), and laser body scanning.

Hydrostatic Weighing

Hydrostatic weighing is a method of determining %BF by measuring the amount of water displaced by a person submerged. This is based on Archimedes Principle, which states that "a body immersed in a fluid is buoyed by a force equal to the weight of the displaced fluid." Thus, if a person is submerged beneath water, the amount of water displaced correlates to the volume of the body (Wagner & Heyward, 1999). The procedure is done by weighing a subject in whatever they will wear underwater before they get in the tank, and again when they are submerged in a known volume of water. The participant will also be required to blow out as much air as possible while submerged to account for any air trapped in the lungs that would make the subject more buoyant. Because muscle and bone is more dense than fat, the more that person weighs underwater compared to above water, the higher percent of their mass comes from muscle or bone and less from fat or vice versa (Cheatham, 2013). Cheatham (2013) provides the following equation which is used to calculate body density using the mass measurements of the subject before and after submersion: Body Density (Db) = BW_{AIR}/ ((BW_{AIR} – (BW_{UWW} – Tare))/ H_2O Density) - (RV +100)). Tare is the known weight of the scale underwater, BW_{air} is the mass of the subject before being submerged, BW_{uww} is the weight of the subject underwater, H_2O is the density of the water dependent on temperature, and RV is residual volume of the subject that is measured (Cheatham, 2013). Using the subjects measured Db, it is possible to calculate %BF using the equation %BF=457/Db – 414.2 or %BF=495/Db – 450 (Pescatello et al. 2014). Hydrostatic weighing has long been considered the gold standard for measuring %BF due to the high accuracy at which it measures (Biaggi et al. 1999), but there are some problems that arise when wanting to use HW. As stated above, subjects must blow out all of their air while underwater to record an accurate reading. Hydrostatic weighing can also be challenging to use on some populations such as children, elderly, or morbidly obese subjects (Vescovi, et al. 2001, Wagner & Heyward, 1999). Also, a researcher must have access to a HW tank and be competent in the procedures for measuring water displacement, Db, and %BF accurately.

Air Displacement Plethysmography

Like HW, ADP is used to calculate %BF by measuring the body volume of a person in relation to mass. Unlike HW, however, ADP measures the air that is displaced instead of water displaced. This procedure is done using an instrument called the BOD POD (Life Measurement Inc., Concord, CA). The subject, wearing a minimal amount of clothing and a swim cap so as little air is trapped inside as possible, is weighed before sitting in the BOD POD, which is a small chamber that holds a known amount of air. The

BOD POD measures the amount of air displaced before having the individual breathe into a tube that measures thoracic lung volume. A computer program then calculates Db and corresponding %BF (Vescovi, et al. 2001). Vescovi et al. (2001) compared %BF measurements recorded by the BOD POD and HW. In total, 95 participants (68 women and 27 men) were measured using both techniques. There was no significant difference in Db or %BF found between HW (22.5% ± 7.3%) and the BOD POD (22.0% ± 7.6%). However, in lean subjects ADP (16.4% ± 4.8%) significantly overpredicted %BF compared to HW (14.1% ± 3.2%). McCrory, Gomez, Bernauer & Mole. (1995) found no difference in %BF or Db between genders when comparing HW and ADP and also determined that ADP was a valid method in determining %BF compared to HW and that the two methods were not significantly different, with a correlation of r=.96. Fields, et al. (2000) compared Db and %BF of 42 adult females and found no significant difference between the BOD POD and HW, but found that the BOD POD underestimated %BF in comparison to the 4-component method which will be discussed later in this review. Fields, Hunter, and Goran (2000) compared the BOD POD to HW in 67 Caucasian females and found a high correlation of r=.97 between the two testing methods. Nunez et al. (1999) tested HW against ADP in 120 subjects (66 females, 54 males) and found a high correlation of r>.90 between the testing methods. In another study by Bentzur, Kravitz, and Lockner (2008), which compared the accuracy of the BOD POD compared to HW in collegiate female track and field athletes, found that the BOD POD significantly overestimated the %BF of the subjects, yet concluded that a strong correlation exists between the BOD POD and HW as a means of measuring %BF (r=.88).

Bioelectrical Impedance Analysis

Bioelectrical impedance analysis is another commonly used tool to assess %BF because the analyzers are fast and easy to operate, and non-invasive for the subject (Wagner & Heyward, 1999). Bioelectrical impedance analysis is measured by a person standing on a scale, holding onto a device, or being hooked up to a device via electrodes. It works the same way for all modes; an electrical signal is sent through the body. The resistance to flow throughout the body is measured by the machine. The age, gender, weight, and fitness level all need to be entered into the program prior to testing and a software program calculates a person's %BF using all of these variables because the volume of fatty tissue correlated to the conductivity of the body. (Cheatham, 2013). Water is a good conductor of electricity, and so there is less resistance to flow in well hydrated tissue (muscle, blood vessels and bones), whereas fat is a poor conductor and thus provides a greater resistance to flow (Reinert, Pohlman, and Hartzler, 2012). Although BIA is an easy and cost-effective method for measuring %BF, the calculations are highly dependent on the hydration status of the individual. Subjects are not supposed to consume any caffeine prior to testing, and often are asked not to eat or drink within four hours of testing, as well as refraining from exercise for up to 12 hours before testing (Cheatham, 2013). Because of this variability, BIA is not as reliable and accurate as other forms of measuring %BF. Thompson et al. (1991) compared BIA to HW before and after an intervention of either an increase in hydration or a combination of exercise and sitting in a hot, humid room to promote water loss via sweat evaporation. Thompson and his colleagues (1991) noted a significant decrease in %BF in the group that was dehydrated due to exercise and sweat loss compared to the control group or increased hydration status group. Hurst et al. (2016) compared the accuracy of BIA to the BOD POD in a heterogeneous sample of adults and found BIA to underestimate %BF by 2%-3% on average compared to the BOD POD and concluded that BIA should be considered a reliable way of measuring %BF.

Skinfold Measurements

Skinfold measurements are another commonly used method for measuring Db and %BF because of the low cost associated with it (Wagner & Heyward, 1999). According to Pescatello et al. (2014), about one-third of all fat is stored subcutaneously. To measure this subcutaneous fat the researcher pinches and slightly pulls the fatty tissue away from the body and measures it by using a caliper that pinches on the sides of the tissue for no more than two seconds (Cheatham, 2013). Landmarks are determined by the formula used to calculate %BF. The ACSM lists three different formulas (7-site, and two 3-site) and the corresponding locations for where the proper measurement should be taken and how it should be taken for each site, and claims accuracy to be within 4-5% (Pescatello et al. 2014). However, ACSM also states that accuracy is dependent on the expertise of the person measuring the sites and pferoper calibration of the calipers (Pescatello et al. 2014). Han, et al. (2012) examined the relationship between HW, BMI, and skinfold measures for 18 college students. The highest standard deviation was found among the skinfold measurements at ± 8.4%, which they attribute to the measurement skills of the technician.

Dual-Energy X-Ray Absorptiometry

Dual-energy X-ray absorptiometry is based on the theory that fat mass fat-free mass have different densities, which is reflected on the scan that is produced by the X-ray. Bone mineral density (BMD) can be measured by the DEXA scan and then subsequently Db, and thus %BF (Wagner & Heyward, 1999). Mazess, Barden, Bisek, and Hanson (1990), measured BMD in 12 young adults using DEXA and determined relative error to be 0.8% fat. This level of accuracy supports the extended use of DEXA as a method for measuring Db and %BF, although anyone hoping to use this method would need access to a machine and know the proper procedure for using it.

Four-Component Model

The four-component model is a method used for measuring %BF by combining multiple methods together in order to calculate more completely and accurately. This is commonly done by modifying the Db measured in HW to determine total-body-water (TBW), using a technique called isotope dilution which measures fat tissue in a known volume, and finally bone mineral which can be found using a DEXA scan (Wagner & Heyward, 1999). Using this data, a tester may use the formula BW=FM + TBW + TBBM + residual (Wagner & Heyward, 1999), where BW is body weight, FM is fat mass, and TBBM is total body bone mineral, and this allows for %BF to be calculated by dividing FM by BW to determine how much of the weight is made up of fat. Fields et al. (2000) compared the BOD POD with the four-component model in adult females and found that the BOD POD significantly underestimated %BF in females compared to the four-component model by an average of 1.8%. Although this technique allows for a more precise and reliable form of measuring %BF, rather than relying on lung volume alone, it is an expensive, time-consuming process that requires much more time and energy to be spent by both the subject and technician (Wagner & Heyward (1999).

Laser Body Scanning

Laser body scanning involves using a laser system that rotates around the body of a subject to create a 3-dimensional representation of that subject's body shape. A computer program can then analyze the person's body volume and subsequent Db, and finally %BF (Pepper, Freeland-Graves, Yu, Stanforth, Xu, 2011). Pepper, et al (2011). conducted a study comparing the accuracy of laser body scanning to HW and DEXA in a heterogeneous group of 70 subjects and found no significant difference in %BF or body volume, and concluded that laser body scanning should be considered a reliable, accurate method to calculate a person's %BF. Garlie, Obusek, Corner, and Zambraski (2010), compared laser body scanning to DEXA in 37 adult males and found no significant difference in %BF, but did find a standard error of estimate to be significantly different (SEE=3.2), suggesting that laser body scanning's measurements closely reflected the findings of the DEXA scan, although further research was encouraged.

Summary

Although there are many currently accepted and used forms of predicting a person's weight classification, personal trainers, nutritionists, doctors, and other professionals who use these methods to determine if a patient or client should gain or lose weight, need an inexpensive, accurate, and simple way of finding out what a person's body composition is. PostureCo is a company that has created a first-of-its-kind application (LeanScreen) that uses photography and reference points to predict a person's BMI, WHR, and %BF, and claims to predict these values to within three percent accuracy. However, the validity of this claim has not been researched to the best of our knowledge.

REFERENCES

Bentzur, K., Kravitz, L., Lockner, D. (2008). Evaluationn of the BOD POD for estimating percent body fat in collegiate track and field female athletes: a comparison of four methods. *Journal of strength and conditioning research*. 22(6). 1985-1991. DOI: 10.1519/JSC.0b013e318185f195

Biaggi, R., Vollman, M., Niew, M., Brener, C., Flakoll, P., Levenhagen, D., Sun, M., Karabulut, Z., Chen, K. (1999). Comparison of air-displacement plethysmography with hydrostatic weighing and bioelectrical impedance analysis for the assessment of body composition in healthy adults. *American Journal of Clinical Nutrition*. 69. 898-903.

Centers for disease control and prevention (2015). Adult obesity facts. Retrieved from https://www.cdc.goesity/data/adulv/obt.html

Cheatham, M. 2013. *Section 6: Body Composition* [PowePoint Slides]. Retrieved from: http://homepages.wmich.edu/~ccheatha/hphe4450/files/handouts/Section06-Body%20Composition-Handouts.pdf

Fields, D., Hunter, G., Goran, M. (2000). Validation of the BOD POD with hydrostatic weighing: Influence of body clothing. International Journal of Obesity and Related Metabolic Disorders. 24(2) 200-205.

Fields, D., Wilson, D., Gladden, B., Hunter, G., Pascoe, D. Goran, M. (2000). Comparison of the BOD POD with the four-compartment model in adult females. Medicine and science in sports and exercise. 1605-1610.

Garlie T., Obusek, J., Corner, B., Zambraski, E. (2010). Comparison of body fat estimates using 3D digital laser scans, direct manual anthropometry, and DXA in men. *American Journal of Human Biology, 22*(5). 695-701.

Han, G., Ko, W., Cho, B. (2012). Relationships among hydrostatic weighing, BMI, and skinfold test results in college students. *Journal of physical therapy science*. 24. 791-793.

Hurst, P., Walsh, D., Conlon, C., Ingram, M., Kruger, R., Stonehouse W. (2016). Validity and reliability of bioelectrical impedance analysis to estimate body fat percentage against air displacement plethysmography and dual-energy X-Ray absorptiometry. *Nutrition and Dietitics. 73*(2). 197-204. DOI: 10.1111/1747-0080.12172

Kavak, V., Pilmane, M., Kazoka, D. (2011). Body mass index, waist circumference and waist-to-hip ratio in the prediction of obesity in Turkish teenagers. *Collegium Antropologicum*. 38(2) 445-451.

Lam, BCC., Koh, GCH,, Chen, Cynthia., Tack, Michael., Wong, Keong., Fallows, S. (2015). Comparison of body mass index (BMI), body adiposity index (BAI), waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) as predictors of cardiovascular disease risk factors in an adult population in Singapore. PLoS ONE. 10(4). Doi: 10.1371/journal.pione.0122985

Lohman, T. (1982). Body composition methodology in sports medicine. *Physician & Sportsmedicine*, *10*(12), 46-47.

Mazess, R B., Barden, H. S., Bisek,J. P., & Hanson,J. (1990). Dual-energy x-ray absorptiometry for total-body and regional bone-mineral and soft-tissue composition. *American Journal of ClinicalNutrition, 51,* 1106-1112.

McCrory, M., Gomez, T., Bernauer, E., Mole, P. (1995). Evaluation of a new air displacement plethysmograph for measuring human body composition. *Medicine and Science in Sports and Exercise*. 27(12), 1686-1691.

National Institute of Diabetes and Digestive and Kidney Diseases. (2012, December). Health risks of being overweight. Retrieved from https://www.niddk.nih.gov/health-information/health-topics/weight-control/health_risks_being_overweight/Pages/health-risks-being-overweight.aspx

Nunez, C., Kovera, A., Pietrobelli, A., Heshka, S., Horlick, M., Kehayias, J., Wang, Z., Heymsfield, S. (1999). Body composition in children and adults by air displacement plethysmography. European Journal of Clinical Nutrition. 53. 382-387.

Obesity information. *American heart association: life is why* (2014) Retrieved from http://www.heart.org/HEARTORG/HealthyLiving/WeightManagement/Obesity/Obesity-Information_UCM_307908_Article.jsp#.V46YM7grKhc

Pepper, M. R., Freeland-Graves, J. H., Yu, W., Stanforth, P. R., & Xu, B. (2010). Evaluation of a rotary laser body scanner for body volume and fat assessment. *Journal of Testing and Evaluation*, *39*(1), 1–6. DOI: 10.1520/JTE102871

Pescatello, L., Arena, R., Riebe, D., Thompson, P. (2014). *ACSM's guidelines for exercise testing and prescription*. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health.

Reinert, B., Pohlman, R., Hartzler, L. (2012). Correlation of air displacement plethysmography with alternative body fat measurement techniques in men and women. *International journal of exercise science*. 5(4). 367-378.

Thompson, D., Thompson, W., Prestridge, T., Bailey, J., Bean, M., Brown, S., McDaniel, J. (1991). Effects of hydration and dehydration on body composition analysis: a comparative study of bioelectric impedance analysis and hydrodensitometry. *The Journal of Sports Medicine and Physical Fitness*. 31(4). 565-570.

Vescovi, J., Zimmerman, S., Miller, W., Hildebrandt, L., Hammer, R., Fernhall, B. (2001). Evaulation of the BOD POD for estimating percentage body fat in a heterogeneous group of adult humans. *European journal of applied physiology*. 85. 326-332. DOI: 10.1007/s004210100459

Wagner, D., Heyward, V. (1999). Techniques of body composition assessment: a review of laboratory and field methods. *Research quarterly for exercise and sport*. 70(2). 135-149.