“Styk-Who?”: A Validation Study of Body Composition Measurement Devices and the Effects on Body Image Perception

Thesis

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Megan E. Kilar, B.S.

Graduate Program in Kinesiology

The Ohio State University

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Thesis Committee

Brian C. Focht, Ph.D., Advisor

Carl M. Maresh, Ph.D.

Abstract

Obesity has become a world-wide epidemic. Despite the health risks obesity and excess adiposity pose, the prevalence of obesity continues to increase. Lifestyle change, including modification of diet intake and exercise/physical activity participation, are now well-established as effective interventions for behavioral weight management, and increasing quality of life and health outcomes. Measuring change in body composition status is a key outcome in the evaluating the effects of lifestyle interventions. However, the most accurate body composition measurement devices are cost prohibitive, reducing their accessibility to underserved populations who typically have poorer health status and outcomes, which places additional limitations on the conclusions drawn from intervention research. Thus, there is a critical need for the development and validation of accurate and accessible body composition measurement devices. Previous research has shown that, compared to traditional criterion methods, 3-dimensional (3D) body scanners have mixed evidence of validity, but are typically highly reliable devices for measuring body composition. Because not all individuals have adequate knowledge of their body composition, contemporary evidence that focuses on potential change in body image perception after learning one's body composition is lacking. Specifically, there has been limited research into the changes in state body image perception, which may be affected by momentary fluctuations in anxiety level, situational contexts, and perceived evaluative threat.

Objective. The primary objective of the present study was to investigate the initial validity of a 3D body scanner ("Styku") against a criterion method (DEXA). A secondary objective was to evaluate changes in state measures of body image outcomes prior to and after body composition analysis.

Methods. The study utilized cross-sectional design to obtain comparative body composition measurements using Styku and DEXA, and pre-post design to collect body image perception before and after body composition analysis. This was one of the first studies to utilize validated state body image questionnaires in body composition measurement research.

Results. A total of 35 individuals were enrolled in the study. Pearson correlation coefficients revealed a high degree of correlation between Styku and DEXA body composition measurements. Intraclass correlation coefficient (ICC) analysis revealed moderate to high degree of agreement between Styku and DEXA measures. Further, Bland-Altman and linear regression analyses revealed mixed evidence of proportional bias between Styku and DEXA measurements. Finally, analysis of change in body image perception revealed a significant change in the Body Image State Scale (BISS), revealing significant declines in BISS after body composition analysis relative to baseline values reported prior to the body composition assessment ($p = 0.03$, Cohen's $d = 0.31$).

Conclusion. As one of the first studies investigating both device validity and changes in body image perception, the findings add to the extant body of literature on both topics.

Specifically, the correlations and limits of agreement between Styku and DEXA measurements are comparable to previous studies, and measured changes in body image perception represent a relatively new finding within the field. Future research should focus on larger, diverse samples and additional subgroup analyses.

Dedication

This is dedicated to my parents, Mary and Richard. Your unwavering support has guided me through all the seasons of my life, and I hope to emulate that support for others.

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Vita

2017..Cardinal Ritter High School

2021.................B. S. *magna cum laude,* Health Promotion, Nutrition, & Exercise Science, The Ohio State University

2021 – 2023..Graduate Associate, Department of Human Sciences, The Ohio State University

Fields of Study

Major Field: Kinesiology, Health & Exercise Science

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Chapter 1. Introduction

Background

In 2011, it was estimated that 34% of U.S. adults were obese, with 15-20% of U.S. children and adolescents also classified as obese (Mitchell, 2011). In the decade that has passed, the CDC estimated that obesity prevalence among U.S. adults rose to 42.4% in 2017-2018 (CDC, 2021). The association between obesity and the development of chronic diseases related to the cardiovascular, metabolic, and musculoskeletal systems is well-known and has wide-ranging effects on healthcare costs (Grundy, 2004; Krauss, 1997; Rashid, 2007). With the growing prevalence of obesity across all age groups in the U.S., it is likely that there will be an uptick in the prevalence of the aforementioned diseases over time.

Because obesity and body composition are strong predictors of disease risk and mortality, it is imperative that there are accurate and reliable ways to measure body composition. There are a wide variety of body composition measurement methods that are regularly implemented across research, clinical, and applied health and fitness settings. Unfortunately, it is well-established each demonstrates its own associated error due to technology limitations or technician error. However, technological innovations have recently yielded a new generation of more accessible body composition devices including three-dimensional (3D) body scanners that are now beginning to be implemented in gyms and health clubs across the nation. Originally developed for the clothing industry, 3D body scanners have been studied as body composition assessment tools in kinesiology (Heymsfield, 2018). Despite promising findings from initial studies of the validity and reliability of 3D body scanners, given the relatively limited extant evidence addressing the validity and reliability of this assessment approach, further research is needed to evaluate the psychometric properties of this innovative, accessible body composition measurement.

Therefore, the primary purpose of this study is to expand the knowledge base of the validity of 3D body scanners, specifically the Styku S100 device. A key aspect of the rationale for conducting the present investigation is that accurate body composition measurement traditional is often cost prohibitive. For example, one of the highly accurate methods is DEXA, but these machines are expensive and not widely available. Devices that measure bioelectrical impedance (BIA) are less expensive, but also less accurate demonstrating substantive measurement error. Compared to DEXA, 3D body scanners are less expensive and more portable, potentially addressing the cost and accessibility limitations and presenting an attractive option for body composition analysis in a variety of research, clinical, and applied fitness environments. A study directly comparing the Styku scanner to DEXA, widely considered a gold standard, criterion measure of body composition, would expand evidence regarding how accurate (valid) Styku and its predictions are. If this, and future studies, provide evidence supporting the validity of the Styku S100, it could ultimately result in making valid, reliable body composition analysis more accessible. This means that the obesity epidemic in the U.S. can be tracked; citizens would be able to monitor their health and body composition, hopefully leading to positive health behavior changes. Although these are lofty goals, the aims of this study represent an initial step required to the process of making valid body composition assessment more accessible in behavioral health promotion and disease prevention efforts.

The secondary aim of this study is to explore the effects of body composition assessment upon state measures of body image perception. As the Styku and DEXA present objective measures of body composition, investigating their effect on body image perception represents a novel research idea, which can expand understanding of the perceptual, affective, and cognitive responses that may impact motivation to complete such assessments thereby advancing a key, understudied aspect of body composition and health behavior.

To date, there is a limited amount of previous research studies that have investigated the potential change in body image perception after body composition analysis. McLester et al. (2018) conducted a study examining social physique anxiety (SPA) responses to a DEXA scan. A total of 212 college-age participants completed pre and post-test assessments of SPA and a follow-up questionnaire focused on potential health behavior change after viewing their scans. It is notable that the post-test health questionnaire was not previously validated, nor was it described in detail in the publication (McLester et al., 2018). Despite these limitations, this study was conducted in a large college-age sample and showed the feasibility of conducting pre- and post-test questionnaires alongside body composition analysis.

Taken collectively, findings from existing studies illustrate the feasibility and value of assessing body image states in a college-age sample. Additionally, the brevity, paired with high content validity, of body image perception questionnaires make them easy tools to use to assess body image perception. The lack of previous studies that have assessed potential changes in body image perception immediately before and after body composition analysis extends the novelty of this study.

Objectives

The primary aim of this study was to investigate the initial validity of the "Styku S100 3D Body Scanner" (Styku, Los Angeles, CA) body composition assessment by directly comparing the measurement properties of the device with those of Dual-Energy X-Ray Absorptiometry (DEXA) (GE Health Care, Madison, WI), a well-established, widely accepted as a criterion measure of body composition. The secondary aim was to examine the effect of body composition measurements on changes in select state body image outcomes using valid, reliable assessments. To achieve this aim, a pretest-posttest design was utilized, integrating assessments of body image outcomes before and following the body composition measurement.

Hypotheses

It was hypothesized that the Styku would have acceptable levels of agreement with DEXA values through correlation and Bland-Altman analyses on various body composition measures. Additionally, it was hypothesized that collecting pre-scan and post-scan body image perception states would be feasible and offer an initial insight to the possibility that becoming aware of one's body composition may affect their body image perception.

Chapter 2. Literature Review

Body Composition and its Relation to Health and Psychosocial Outcomes

Body composition is the measurement of fat, lean, and bone mass within the human body (UC Davis Sports Medicine, 2023). The masses and relative percentages of these tissues can have distinct health implications and, as such, body composition is a key outcome measure in numerous research studies. Additionally, the advent of new technology has made body composition analysis more accessible to a wider subset of the population outside of research and clinical settings. Importantly, body composition can have predictive value in determining disease risk. Bogers et al. (2007) found increased risk ratios of incident coronary heart disease in overweight and obese individuals (RR = 1.33 and 1.69, respectively). Overweight and obesity also increase the relative risk of at least ten different types of cancer (Calle & Kaaks, 2004). Concomitant with the increased risk of disease incidence, overweight and obesity are predictors of all-cause mortality. Most of these epidemiological analyses have relied on cohort studies with select concerns regarding research methods, especially potential confounding variables of chronic disease and smoking statuses, and age. However, the extant data reveal U-shape curved relationships between body mass index and relative risk of death with underweight and overweight individuals have increased risk compared to normal-weight individuals, while obese individuals have the highest risk of mortality compared to any other group

(Manson et al., 2007). The heightened disease risk caused by being overweight or obese underpins the importance of accurate body composition measurement. Moreover, there is growing evidence that the location of adiposity meaningfully influences disease incidence and risk, with deaths mostly attributed to cancer and cardiovascular disease (Hu, 2008; Zhang et al., 2008). It is important to note, region-specific body adiposity must also be considered based on the evidence that it can increase mortality risk. As such, body composition measurements that can account for overall and regional adiposity should be considered standard practice methods in research, health, and disease prevention efforts.

Disease outcomes aside, obesity can have effects on health-related quality of life (HRQOL), psychosocial outcomes, and health behaviors. In fact, obesity, and diseases it is strongly associated with, can prevent individuals from completing activities of daily living, increase healthcare costs, and may mediate additional poor health behaviors (Hu, 2008). Many previous research studies focused on obesity and its effect on HRQOL have measured only BMI as an indicator of obesity, which is limited in scope (see "Body Composition Measurement Methods"). In fact, in a systematic review on this topic, only one study quantified body fat percentage (BF%) and found associations between higher BF% and more anxiety and depression (Hu, 2008). As additional research addressing these issues continues to emerge, there is a link between physical health status (i.e., body composition, or BF%) and HRQOL as well as psychosocial outcomes, like depression and anxiety, that warrants further inquiry. In the present study, it was hypothesized that gaining knowledge of one's body composition may influence change in select state body image outcomes, such as state social physique anxiety, defined as "apprehension in response to the presence or prospect of negative physique evaluation" (Hart, Leary, & Rejeski, 1989). Alterations in state body image responses may subsequently have important implications for motivation for body composition assessment and behavioral weight management efforts.

Measurement of body composition is not the only instance in which individuals are "confronted" with their physique. In samples of females with high baseline social physique anxiety, results showed that the exercise environment has an impact on state anxiety based on the evaluative threat ("negative physique evaluation") posed by the environment itself (Focht & Hausenblas, 2003). These results relate to the present study in that the process of undergoing evaluations of body composition represents a situation that may elicit perceptions of physique-related evaluative threat that result in unfavorable changes in body image outcomes such as state physique anxiety.

Exercise has been posited as a method by which to improve physical and mental health status, including body composition and anxiety. However, the exercise environment, and the evaluative threat it poses, can mediate the affective response to exercise. Focht and Hausenblas (2006) found that evaluative threat did mediate state anxiety responses to exercise. However, long-term improvements in physical and mental health are not seen with a single dose of exercise. Results from this study highlight the importance of environments with low perceived evaluative threat for those with poor body image or those whose body image perception precludes them from participating in regular exercise.

Body image has been investigated in relation to indicators of mental and physical health. Wilson and colleagues found that BMI was moderately associated with poorer physical HRQOL (r = -0.28 and -0.21, for men and women, respectively) and mediated by poor body image (2013). However, body image dissatisfaction was associated with or predicted poor physical and psychosocial functioning, but BMI alone did not. A similar study utilized a sample of undergraduate students and found that those who had positive body image had fewer depressive symptoms, higher self-esteem, fewer unhealthy dieting patterns, lower desire for muscularity, and higher intentions to protect their skin against UV damage (Gillen, 2015). These results are also independent of BMI, which means that objective body size did not have an effect on these mental and physical health indicators. Results from these studies combined may cause researchers to re-focus their intervention studies on body image perception instead of physical health outcomes (i.e., body composition) to promote healthy behaviors. However, body composition should still be a key outcome based on its significant relationship with disease risk and physical health outcomes.

Body Composition Measurement Methods

Underpinning the relationship between health outcomes and body composition are accurate body composition measurement methods. There is a plethora of methods to choose from, with advantages and disadvantages to each. Recently, 3-dimensional (3D) body scanners have grown in popularity due to their low cost, portability, and ease of use. Due to the nascency of these devices, it is critical to evaluate their validity against standard, well-established criterion methods prior to accepting their widespread use. To understand the rationale for validating a 3D body scanner as an accurate body composition measurement device, a summary of the existing methods of body composition analysis is presented. The methods included in this review do not constitute an exhaustive list. Table 1 summarizes the standard error of estimation (SEE) of each method discussed.

Indirect Methods

Indirect methods estimate body composition based on other results from criterion methods. The estimation given with these methods is dependent upon direct and criterion measures and their distribution among a large sample of individuals. Indirect methods include anthropometry (weight, stature, body mass index (BMI), circumferences, and skinfolds) and bioelectrical impedance analysis (Duren et al., 2008). Largely, indirect methods are simple to use, portable, and are of low cost, making them easily accessible body composition methods regardless of setting.

Anthropometry. Widely, anthropometry is a basic body composition measurement method that describes the body's shape, size, and fatness (Duren et al., 2008). Standardized anthropometric techniques exist and aid in body composition measurement and comparison to others.

Weight, Stature, and BMI: Weight is perhaps the simplest approach to assess body composition, however it's validity as a measure of body composition is greatly limited in scope (i.e., it is unknown what a person's weight is composed of), and changes often throughout the lifetime for various reasons. Likewise, stature or height is a simple measure that is highly related to weight. Taken together, height and weight can produce a body composition value known as body mass index (BMI, weight divided by height squared; kg/m^2), which adds specificity to a simple weight-only measurement. The larger limitations with weight- and height-based measurements are the lack of specificity in body tissue proportions and differing body compositions throughout life stages and in athletic populations that cannot be accounted for by these methods (Duren et al., 2008).

Circumferences: Excess body fat located around the central abdomen is highly correlated with chronic conditions, like hypertension, metabolic syndrome, type II diabetes mellitus, stroke, cardiovascular disease, and dyslipidemia (Coutinho et al., 2013; Janssen et al., 2022). Understanding the pattern of body fat distribution can assist in determining health risk levels. For example, android obesity, which is characterized by high abdominal fat levels, carries a higher risk of premature death and chronic disease than gynoid obesity, which is higher fat levels distributed throughout the hips and thighs (Tanamas et al., 2016; Tchernof & Després, 2013). Prediction of body fat percentage from body circumferences is completed using regression equations with a standard error of estimate (SEE) of 2.5-4.0% (Tran et al., 1988; & Tran et al., 1989).

Skinfolds: Skinfold assessment estimates body fat percentage by measuring the thickness of different sites of skinfolds throughout the body. Large variation exists in body fat deposition between individuals, but population, age, and gender-specific regression equations exist that reduce prediction error (ACSM, 2022). Skinfold assessment yields body fat percentages that correlate highly (r = 0.70-0.93) with criterion methods, including hydrodensitometry, air displacement plethysmography, and dual-energy X-ray absorptiometry (ACSM, 2022; Heymsfield et al., 2015; Hillier et al., 2014; Jackson et al., 2009). Limitations of this method include technician experience and calipers with an upper limit of 45-50 mm, which may not be sufficient for severely obese individuals (ACSM, 2022; Duren et al., 2008). Prediction of body fat percentage from skinfold assessment has a standard error of estimation of 3.5% (ACSM, 2014).

Bioelectrical Impedance Analysis (BIA). Bioelectrical impedance analysis devices estimate body composition by measuring the resistance of body tissues to an electric current (Ceniccola et al., 2019). Studies have examined the accuracy of BIA in surgical and cancer patients in which researchers found the accuracy was substantially lower than in “healthy” populations (Haverkort et al., 2015). The primary limitation is this method is its sensitivity to the hydration status of the participant. Because of this, researchers and practitioners should utilize this method to assess longitudinal changes in body composition (Ceniccola et al., 2019). The standard error of estimation for BIA is 3.5-5.0% (ACSM, 2014).

Criterion Methods

Criterion methods differ from indirect methods in that they measure a specific property of the body, typically the density or amounts and distributions of various body tissues (Duren, 2008). The criterion methods described here are not an exhaustive list; instead, a description of the most widely used criterion methods is included.

Hydrodensitometry (HD). Typically known as “underwater weighing (UWW),” hydrodensitometry estimates body composition through direct measurement of body weight and volume, and residual lung volume. Procedures for conducting underwater weighing include complete exhalation and submersion in a tank outfitted with a weight scale, which precludes some individuals from participating, especially children and larger participants (Duren, 2008). If participants can comply with underwater weighing procedures, it is considered a valid measure of body composition. The standard error of estimation for hydrodensitometry is 2.5% (ACSM, 2014).

Air Displacement Plethysmography (ADP). Similar to underwater weighing, ADP can also measure body volume and, thus, body composition (ACSM, 2022). ADP is an expensive method but may be more favorable for individuals who are uncomfortable with submerging underwater. Limitations of ADP include cost, tissue density assumptions across demographic groups, and clothing requirements for testing (Duren et al., 2008). The standard error of estimation for ADP is 2.2-3.7% (ACSM, 2014).

Dual-Energy X-ray Absorptiometry (DEXA). Considered the gold standard body composition analysis device in sarcopenia, DEXA is able to analyze fat and lean tissue, and bone mineral content regionally, or of the entire body (Ceniccola et al., 2019). DEXA utilizes two low-energy level x-rays that differentiate the three different tissues (Duren et al., 2008). Although there are more detailed analysis devices, including computed tomography (CT) and magnetic resonance imaging (MRI), DEXA measurements are well correlated with CT and MRI (Tewari et al., 2018; Xu et al., 2011). Despite the accuracy of DEXA, it is not a portable body composition measurement device, is costly, and systems differ in their ability to accommodate select body sizes such as very large and/or tall individuals. Comparatively, these disadvantages do not preclude DEXA from being considered the current reference technique for body composition. The standard error of estimation for DEXA is 1.8% (ACSM, 2014).

Critical Need for Accessible Measurement and its Utility in Various Applications

Implications for Lifestyle Interventions in Health Promotion & Disease Prevention

As previously discussed, there is a critical need to understand changes in body composition as it relates to disease risk, health, and psychosocial outcomes. In lifestyle interventions where body weight or composition is a key outcome, it is imperative that valid and reliable technologies are available for use. In fact, in many randomized controlled, lifestyle intervention trials aimed at weight loss, the standard of body composition analysis is DEXA or BIA (Danielsen et al., 2013; Horne et al., 2020; Focht et al. 2022).

Likewise, in trials with cancer patients and survivors, body composition measurement is a key outcome. Chaplow and colleagues (2020) have reported on body composition outcomes in a prostate cancer lifestyle intervention, which showed significant improvements in body composition using DEXA. Ongoing data analysis from the same research group is focused on body composition outcomes from lifestyle interventions in breast and head and neck cancer patients and survivors.

The previously discussed lifestyle interventions are set in urban areas, where access to health care is more ubiquitous. However, health disparities exist between urban and rural communities. For example, rural residents are less likely to have insurance, and receive preventative healthcare services, while having a higher prevalence of chronic diseases, such as diabetes and obesity (Bennett, Olatosi, & Probst, 2008). In rural settings worldwide, researchers have mostly relied on BIA, BMI, skinfolds, and circumference measurements to assess body composition outcomes (Cesani et al., 2013; Draper et al., 2017; Forbes et al., 2019; Smith, Petosa, & Laurent, 2019; Tan et al., 2019). DEXA has been used in rural populations (Feng et al., 2012), but its application in rural populations is limited in extant literature due to its limited portability and high cost despite its accuracy (Smith, Petosa, & Laurent, 2019). Thus, there remains a critical need for portable, accessible body composition measurement devices for use in underserved and/or rural populations. The development of 3-dimensional (3D) body scanners over the past 20 years may be applicable in this setting. However, there is a dearth of literature on the validity of these devices, especially the Styku S100. Although 3D body scanners may fill a gap in the body composition device industry, their validity and standard error of estimation remain to be elucidated.

Previous Evidence of Styku S100 Validity

Tinsley and colleagues (2020) compared four 3D scanners (Fit3D, Size Stream, Styku, and Naked Labs) to ADP and DEXA (2020). Conclusions from this study found that the Styku system produced reliable results, but the precision or accuracy of circumference measurements depended on the proprietary landmarking sites and formulas used by each manufacturer. Additionally, results also showed that DEXA-derived body volume had lower error rates than the 3D scanners when compared to ADP results with Styku underestimating body volume overall. This study was limited in scope in that it only analyzed validity within body volume measurements and did not quantify body fat or lean mass percentages, which could assist in determining whether or not the Styku system is valid and extend the results to disease risk mitigation.

Various 3D scanners have been compared against manual circumference measurements, and ADP and DEXA volume measurements. Bourgeois et al. (2017) found that three 3D scanners (KX-16, Proscanner, and Styku) produced circumferences with high correlation (R^2 = 0.71-0.96) to manual circumferences and body volumes with high correlation (R^2 = 0.69-0.99) to ADP and DEXA. However, researchers once again did not quantify nor compare the body fat and/or lean mass percentages given by these methods, which limits the translational validity of the Styku scanner.

In a recent cross-sectional analysis of body composition comparing DEXA and "Naked Labs 3D Fitness Tracker," VanSumeren and colleagues (2022) found that the 3D scanner estimates of body fat percentage (BF%) were significantly lower than DEXA (Cohen's d = 1.0), with males exhibiting lower BF% on the 3D scanner compared to DEXA, and females exhibiting non-significantly different BF% in each device, on average. Although this study was conducted on the Naked Labs' 3D scanner and not the Styku, the systems are very similar in design and methodology. Results from this study support the need for additional research into the body composition results from 3D body scanners.

Harbin and colleagues (2018) conducted a validation study on an older version of the Styku scanner called "MYBODEE". In this study, researchers compared BF% results from the 3D scanner to hydrostatic/underwater weighing (UWW), bioelectrical impedance (BIA), skinfolds, and manual circumferences. Results showed that BF% from the 3D scanner was significantly lower than BF% from UWW, BIA, skinfolds, and manual circumferences (Harbin et al., 2018). The authors note that as adiposity increased in study participants, the precision of the 3D scanner decreased. These results have important implications, especially considering the rising obesity epidemic and the need for accurate and accessible measurement devices.

In another recent study, Cabre and colleagues (2021) conducted a validation study on the Styku scanner against DEXA and a 4-compartment (4C) body composition model. The results of these comparisons showed no significant differences in body composition measurements compared to DEXA but did find significant differences in BF% compared to the 4C model with the Styku overestimated BF%. In both males and females, the differences in body composition measurements from Styku and DEXA were not significant. As one of the most comprehensive validation studies on the Styku to date, independent replication of these results is vital.

Although there has been evidence showing the validity of the Styku S100 system, it is important that independent replication occurs. In the current study, comparisons were made between body composition analysis using the Styku S100 and DEXA as the criterion method. This comparison is not new, but the sample included in the current study was limited to participants aged between 18 and 40 years, which is a markedly smaller age range than has been utilized in previous validity studies.

Body Image: Definition, Measurement, and Associations with Health Behaviors

Cash (2004) defines body image as “the multifaceted psychological experience of embodiment, especially but not exclusively one’s physical appearance.” Inherent in this definition are various dimensions of body image, including perceptual, affective, cognitive, behavioral, and subjective satisfaction (Martin-Ginnis et al., 2012). The combination of these dimensions gives an overall index of one's body image. Body image outcomes are frequently measured using questionnaires designed to assess select dimensions of body image. For example, the Body Image States Scale (BISS), developed by Cash and colleagues (2002), measures subjective and affective dimensions of body image across different situational contexts. There is a plethora of available questionnaires for use in body image perception research, which is mainly fueled by the relatively recent surge of interest in body image research and emphasis on physical appearance (Shroff et al., 2009). An important consideration researchers must make is whether they are targeting the measurement of state or trait body image (described in detail below). Additionally, many questionnaires available for research have been standardized using small sample sizes, which limits their reliability and validity (Shroff et al., 2009). Although this is a limitation of the research, selecting questionnaires that are most appropriate for the research sample characteristics and demographics (age, sex or gender identity, athletic status, eating disorder risk) will add to the methodological rigor of the research.

A complex constellation of factors contributes to negative body image including societal and cultural influences, family dynamics, and individual propensity for weight gain among other factors. Moreover, body dissatisfaction is linked to eating disorders, depression, and obesity (Gillen & Markey, 2016). Although a causal relationship has yet to be elucidated, it is widely accepted that there is a potential for reciprocal causation between body dissatisfaction and other health concerns.

As discussed previously, body composition, body image, and state anxiety are intricately related. Although there is no panacea for obesity or state anxiety, positive health behaviors can have beneficial effects on physical and mental health. However, negative body image can have negative impacts on sleep, nutrition, and physical activity; meanwhile, positive body image is associated with positive health behaviors (Becker et al., 2019). Just as there appears to be reciprocal causation between body dissatisfaction and mental and physical health outcomes, the relationship between body image and health behaviors may exist in a reciprocal nature as well, which may present challenges in future intervention research.

State and Trait Body Image Perception & Measuring Potential Change

Body image perception is defined as the collection of cognitions, including attitudes, towards one's own body, especially regarding its appearance (Cash, 2002). Because of temporal instability of body image perception, most previous research has focused on "trait" body image perception and/or social physique anxiety, where the emphasis was placed on facets of body image and physique anxiety that were stable characteristics of participants, with relative consistency across situations (Endler & Kocovski, 2001).

Contrasted with trait body image disturbance dimensions which reflects one's general predisposition towards experiencing cognitive, affective, and perceptual body image concerns, state physique anxiety and body dissatisfaction reflect immediate, transient changes in facets due to a stimulus, which can include information and images, situational contexts, and interpersonal events (Cash, 2002). In previous studies, researchers typically utilized trait body image scales, modifying their wording to reflect state body image perception, and thus were left with non-validated assessment tools and data. Recently, scales have been created and validated to accurately measure state body image perception. However, these scales have been underutilized in body composition studies, which could have a large impact on one's state body image perception. The current study presents data and images on participants' body composition, thus there may be a large situational impact on body image perception, specifically state body image perception. In fact, measuring potential changes in state body image perception research using informational stimuli (i.e., body composition data and images) requires the use of measures that can adequately capture momentary changes (Cash, 2002).

The Body Image States Scale (BISS) is a "multi-item measure of momentary evaluative/affective experiences of one's physical appearance" (Cash, 2002). The BISS targets six domains of current body experience (Table 2), evaluated in the current moment. Internal consistency for the BISS was 0.77 and 0.62 for women and men, respectively. Test-retest reliability was measured at 0.69 and 0.68 for women and men, respectively. Moreover, lower BISS scores (i.e., more negative body image perception) were correlated with higher body mass index (BMI) (r = -0.53 and -0.46, for two time points for women; r = -0.34 and -0.31 for two time points for men). This observation is consistent with previous literature that found overweight and obese individuals are more likely to experience negative body image perception (Cash, 2002). Although these correlations are moderate and modest for women and men, respectively, they do showcase the potential for differing state responses to body image scales based on BMI.

Additionally, the BISS was validated in a college-age sample and showed that women had less favorable body image states than men. This validation study used a repeated measures design, where participants answered the questionnaire in two visits, separated by 2-3 weeks between measurements. In a follow-up study, researchers used the same BISS questionnaire to assess day-to-day fluctuations in body image states (Rudiger, 2007). Results from this study showed that greater variability in body image states was mediated by greater investment in appearance, cognitive distortions, and perfectionistic self-presentation.

Similarly, the State–Social Physique Anxiety Scale can also tap into momentary changes in perceived body image-related anxiety in social settings. The scale specifically asks about instantaneous evaluations of subjects' affective dimension of body image in a nine-item, Likert-scale questionnaire (Martin-Ginnis, 2010). To date, this scale has not been validated in male samples, and thus, its inclusion in the present study has limited validity. However, previous research has investigated the potential effect of experimenter gender on S-SPAS scores between men and women and found that there was no significant effect of experimenter gender on S-SPAS score, although women scored significantly higher (higher state social physique anxiety) than men (Lamarche, Gammage, & Gabriel, 2011). Future research is needed to determine the validity of the S-SPAS in male samples, and potential experimental variables that affect participant scoring.

Previous research is limited in regard to measuring the potential change in body image perception before and after body composition analysis. McLester and colleagues utilized a version of the Social Physique Anxiety Scale using prior to a DEXA scan in a college-age sample. Pre- and post-testing questionnaires focused on health behavior change were administered. However, these questionnaires were not validated and not detailed in the publication (McLester, 2018). Despite its limitations, this study provided foundational knowledge and feasibility of conducting body composition analysis alongside body image perception measurement.

Chapter 3. Methods

Overview

The primary objective of the present study was to investigate the initial validity of a 3D body scanner ("Styku") against a criterion method (DEXA). Given body composition measurement devices are relatively expensive and large or cumbersome, body composition analysis is either cost-prohibitive or inaccessible. One of the most accurate methods of body composition measurement is dual-energy x-ray absorptiometry (DEXA), but these devices are expensive, not widely available, and require certification to operate. Compared to DEXA, 3D body scanners, like the Styku S100, are less expensive and highly portable. These scanners present an accessible option for body composition measurement in various applications. Comparing the Styku to DEXA was theorized to give researchers a better idea of the validity of the Styku when considering the DEXA as the present-day gold-standard body composition analysis device.

The secondary aim of this study was to measure state body image perception using validated questionnaires before and after body composition analyses were conducted. Both body composition measurement devices offer objective data on one's body composition. Investigating their potential effects on state body image perception represented a novel research idea, which could expand future research linking body composition with psychosocial outcomes.

Participant Eligibility

Interested participants had access to a digital eligibility screening tool, using Microsoft Forms. Information collected in this screening included name (first and last), sex, age (not birthdate), and email contact. Responses to this eligibility form were stored under the digital, password-protected Microsoft application. Respondents received communication from study staff via the email provided in the screening form to confirm or deny their eligibility for the study.

Eligible participants were between the ages of 18-40 years, were able to understand English, able to give informed consent to participate in study procedures and attend a 1-hour study assessment. For female participants, a negative pregnancy test completed after the consent process was required in order to participate in the assessment due to radiation exposure from the DEXA scan. If a female participant consented and had a positive pregnancy test, none of the study measures were collected.

Recruitment

The target accrual for this study was, at minimum, 30 participants and maximum 50 participants. It was expected that this accrual goal would be easily met based on previously successful recruitment for studies in the Exercise and Behavioral Medicine Laboratory. Recruitment flyers were posted around Ohio State’s Columbus campus. Additional recruitment emails were sent to university departments using departmental list-servs. The recruitment flyer included general details of the study, inclusion criteria, and a link to the eligibility screening tool.

Informed Consent

Approval of trial protocol and informed consent documents was obtained from the Ohio State University Institutional Review Board (IRB) prior to the initiation of recruitment procedures. All potential study participants were adults who were able to provide informed consent to participate in the research study. Interested individuals contacted to participate in the study were given an overview of the study before engaging in the consent process. Informed consent was obtained at a scheduled assessment time during the study. After scheduling this assessment, participants were given a digital copy of the informed consent document that was reviewed once again and signed at the beginning of the assessment. The document addressed the procedures, participant requirements, benefits, and risks associated with the study. The document explained to participants that their participation in this study would not affect their relationship with the university, our department, or study staff. Within the document, it was expressed that, although there is only a single assessment, participants have the right to withdraw from the study at any time with no penalty. Participants were free to review and make their decision whether or not to participate. Only those interested participants who signed the informed consent document were able to participate in the study. Study staff knew and complied with IRB guidelines concerning participant privacy and confidentiality.

Measures

Body Composition Measurement

Anthropometrics. Body weight was measured to the nearest 0.1lb using a calibrated and certified balance beam scale. Height was measured to the nearest 0.25in using a certified stadiometer. Anthropometric measurements were taken in a private consultation room to maintain participant privacy.

DEXA. DEXA was used to measure body composition, including percent body fat and fat-free mass for all body regions, bone mineral density, and regional body density. DEXA scans were completed in a private consultation room to maintain participant privacy.

Styku. The Styku S100 3D body scanner was used to measure body composition, including percent body fat, fat-free mass, bone mineral content, and regional body density. Styku scans were completed in a private consultation room to maintain participant privacy.

Questionnaires

Demographic Questionnaire. A demographic questionnaire was used to gather information on various characteristics of the study sample. Questions included information on the following topics: age, sex, ethnicity, education level, and employment status.

International Physical Activity Questionnaire (IPAQ). The International Physical Activity Questionnaire asks subjects about their physical activity over the previous seven days, broken down into vigorous and moderate intensity activities, and walking activity. As a subjective measure of physical activity, the IPAQ allowed respondents to self-report whether or not they participated in a type of physical activity and to quantify the amount of time spent doing that activity over the past seven days (Craig, 2003).

Satisfaction with Physical Function and Physical Appearance (SPFPA). The Satisfaction with Function and Appearance questionnaire is a 9-item scale that consists of six items that assess satisfaction with physical function and three items tapping satisfaction with body appearance. Each item was rated on a 7-point scale that is scored from -3 to +3 with numbers on the scale anchored by the following phrases: very dissatisfied (-3), somewhat dissatisfied (-2), a little dissatisfied (-1), neither (0), a little satisfied (+1), somewhat satisfied (+2), very satisfied (+3) (Reboussin, 2000). The first six items of this scale are averaged to measure satisfaction with function and the last three items are averaged to measure satisfaction with appearance. Averages can range from -3 to +3.

State Social Physique Anxiety Scale (S-SPAS). The State–Social Physique Anxiety Scale is a version of the Social Physique Anxiety Scale developed to evaluate body image-related anxiety in social situations. The State scale specifically asked about instantaneous evaluations of subjects' body image in a nine-item, Likert-scale questionnaire (Martin-Ginnis, 2010). The S-SPAS score is recorded as an average of the nine items, with higher scores representing higher state social physique anxiety. The possible range of scores is 1 – 5.

Body Image States Scale (BISS). The Body Image States Scale is a six-item, Likert-scale questionnaire that taps into participants' current, momentary feelings about their overall physical appearance, body size and shape, weight, attractiveness, looks relative to how they usually feel, and evaluation of their appearance relative to how the average person looks (Cash, 2002). The BISS score is recorded as a sum of the six items, with lower scores representing worse state body image. The possible range of scores is 9 – 54.

Procedures

Assessments of body composition and body image questionnaires were conducted by trained study staff. Assessments were completed at the Ohio State University, in the PAES Building. Participants only attended one study assessment that included the following: informed consent, pre-test questionnaires and demographics, Styku scan, DEXA scan, result interpretation, and post-test questionnaires. Female participants were required to take an HCG urine pregnancy test with a negative result after consent and prior to pre-test questionnaires to participate. Table 3 shows an outline of all study measures.

Data Analysis and Trustworthiness

Descriptive statistics were run on the demographic characteristics of the sample. Statistical analyses regarding body composition comparison hinge on Pearson correlation, intraclass correlation (two-way mixed effects, absolute agreement, multiple raters/measurements) and Bland-Altman analyses comparing the level of agreement between the two measurement devices. Interpretation of strength of correlational relationships was based on previous guidelines (Koo & Li, 2016; Schober et al., 2018). Interpretations of Bland-Altman analyses were also based on previously established guidelines (Myles & Cui, 2007). Analyses of changes in body image outcomes were measured using paired samples t-tests, with a significance level of p = 0.05. Additionally, effect sizes (Cohen's *d*) were calculated to determine the magnitude of the difference in the pre-to-post assessment changes in state body image outcomes. All analyses were conducted using SPSS 27.0 (IBM SPSS Statistics for Mac, Version 27, Armonk, NY; IBBBM Corp.).

Chapter 4. Results

Participants & Demographics

The study sample consisted of 35 young adults between 19 and 37 years of age (20 women, 15 men; 25.63 $\pm$ 4.941 years of age). Figure 1 illustrates the flow of the study from eligibility screening, enrollment, assessment, and data analysis. Table 4 summarizes additional demographic factors.

Satisfaction with Physical Function and Physical Appearance (SPFPA)

Physical Function Subscale. The average satisfaction with physical function was 9.37 $\pm$ 5.21, 10.05 $\pm$ 5.22, and 8.47 $\pm$ 5.24 for the total sample, females, and males, respectively.

Physical Appearance Subscale. The average satisfaction with physical appearance was 4.51 $\pm$ 3.67, 4.60 $\pm$ 3.63, and 4.40 $\pm$ 3.83 for the total sample, females, and males, respectively.

Body Composition: Measurement Means and Standard Deviations

Table 5 summarizes the means and standard deviations of body composition measurements made by Styku and DEXA. Only 34 participants had their body composition measured by the Styku due to a Styku software error during a participant assessment.

Body Composition: Pearson Correlations

Bivariate correlation analyses revealed strong correlations between body mass, body fat percentage, fat mass, lean mass percentage, lean mass, and bone mass measurements made with Styku and DEXA measurements (Pearson $r = 1.000$, 0.839, 0.802, 0.838, 0.971, and 0.891, respectively). Partial correlation analyses controlling for sex revealed very strong correlations for body mass and lean mass (Pearson $r = 0.999$ and 0.899, respectively); strong correlations for fat mass and bone mass (Pearson $r = 0.766$ and 0.796, respectively); and moderate correlations for body fat percentage and lean mass percentage (Pearson $r = 0.579$ and 0.561, respectively) between Styku and DEXA measurements. Body composition correlations are summarized in tables 6 and 7.

Body Composition: Intraclass Correlation Coefficients

Table 8 summarizes the intraclass correlation coefficients and 95% confidence intervals for all body composition comparisons made between DEXA and Styku. An excellent degree of agreement was found for measurements of body mass and lean mass between methods with average measure ICC = 1.000 (95%CI = 0.998, 1.000; $p < 0.001$) and 0.978 (95%CI = 0.937, 0.990; $p < 0.001$), respectively. Additionally, a good degree of agreement was found for measurements of body fat percentage, fat mass, and lean mass percentage between methods with average measure ICC = 0.889 (95%CI = 0.761, 0.947; $p < 0.001$), 0.847 (95%CI = 0.583 0.934; $p < 0.001$), and 0.883 (95%CI = 0.716, 0.947; $p < 0.001$), respectively. A moderate degree of agreement was found for measurements of bone mass between methods with average measure ICC = 0.734 (95%CI = -0.184, 0.917; $p < 0.001$).

Body Composition: Bland-Altman Analysis of Limit of Agreement

Bland-Altman plots are presented in figures 2-7. Table 9 includes additional data from linear regression analysis of the Bland-Altman statistics. Bland-Altman plots revealed mixed evidence for proportional bias between DEXA and Styku measurements in body mass, body fat percentage, fat mass, lean mass percentage, lean mass, and bone mass ($p < 0.001$, $p = 0.035$, $p = 0.133$, $p = 0.086$, $p = 0.027$, and $p < 0.001$, respectively).

State Body Image Outcomes

Table 10 summarizes the means and standard deviations for the BISS and S-SPAS pretest and posttest scores by sex and for the total sample.

State Social Physique Anxiety Scale (S-SPAS). There was a non-significant pretest-posttest difference in the S-SPAS score for the total sample ($t = -1.80$, df = 34, $p = 0.08$, Cohen's $d = -0.15$). Results of effect size analyses demonstrate the changes between pretest and posttest with the S-SPAS are negligible and not of clinical significance.

Body Image States Scale (BISS). There was a significant pretest-posttest difference in the BISS score for the total sample ($t = 2.26$, df = 34, $p = 0.03$, Cohen's $d = 0.31$). Although the effect size is small, there remains a significant difference in pretest and posttest scores on the BISS.

Chapter 5. Discussion

The primary objective of the present study was to investigate the initial validity of a 3D body scanner ("Styku") against a criterion method (DEXA). A secondary objective was to evaluate changes in state measures of body image outcomes prior to and after body composition analysis.

Body Composition

Results from the analysis of body composition measurements in this study reveal mixed results. The Pearson correlation coefficients reveal very strong or strong correlations between measurement devices for most body composition outcomes. When controlled for sex, the Pearson correlations were modestly attenuated, which is expected due to the effect of controlling for additional variables. Pearson correlations from the present study are similar to those found in internal research done internally at Styku, Inc. using DEXA as the criterion method, with ranges for all body composition outcomes of 0.64-0.96 (Sareen, 2018). Notably, Styku produced much higher correlations for fat mass compared to the current study (R = 0.96 and 0.766, respectively). However, when not controlling for sex in Pearson correlation analyses, the results of the present study differ from those seen in Cabre et al. (2021). Compared to DEXA, Cabre and colleagues measured Pearson correlation coefficients of 0.86, 0.90, and 0.90 for body fat percentage, fat mass, and lean mass, respectively. Although the results of the present study align with body fat percentage (*R* = 0.839), the present findings do differ considerably in fat mass and lean mass (*R* = 0.802 and 0.971, respectively). In comparison to underwater weighing, bioelectrical impedance analysis, skinfolds, and circumferences as criterion methods, the Styku scanner estimations of body fat percentage correlated strongly as evidenced by Pearson correlation coefficients in the range of 0.816-0.888 (Harbin et al., 2018), which is similar to the present study. Despite the emphasis placed on body fat percentage for health risks and outcomes, additional research should analyze the correlation of lean mass, bone mass, and additional body composition outcomes to create a holistic understanding of the correlation between measurement methods.

Studies reporting ICC values between Styku and DEXA remain limited. In the present study, all body composition comparisons made between Styku and DEXA had significant ICCs with $p < 0.001$. This gives one indication as to the substantive extent of the measurement agreement between Styku and DEXA. Specifically, Styku and DEXA measurements of body mass and lean mass had excellent agreement. Similarly, measurements of body fat percentage, fat mass, and lean mass percentage had good agreement, and measurements of bone mass had moderate agreement when considering ICC values. Although Styku body composition measurements have been compared to DEXA, there is a lack of studies that have reported ICC values. Consequently, future research should include these values to give a better picture of agreement and validity of the Styku device.

Visual and statistical inspection of the Bland-Altman plots and linear regression analyses reveal mixed proportional bias in body composition measurements. For example, the Styku underestimated body mass, lean mass, and bone mass, and overestimated body fat percentage compared to the DEXA criterion method. Nonetheless, it is critical to note measurement differences in fat mass and lean mass percentage did not reach statistical significance. Analyzing limits of agreement can augment visual analysis and offer insight into clinical significance.

Bland-Altman plots of limit of agreement for body fat percentage, fat mass, and lean mass are similar to those reported by Bennett et al (2022). However, when directly compared to the limits of agreement presented by Cabre et al. (2021), the limits of agreement in the present study are much larger for measurements of body fat percentage, fat mass, and lean mass. In fact, the 95% limit of agreement is large in each body composition measurement except for body mass, which means variability exists in measurements between devices. Smaller 95% limits of agreement are desired to offer evidence of measurement validity of the investigative device.

From a clinical perspective, body fat percentage and bone mass are important indicators of health status and risk. In this study sample, Styku overestimated body fat percentage and underestimated bone mass compared to DEXA with very large 95% limits of agreement. With an average difference of approximately 2% body fat, this measurement difference is clinically relevant, especially when considered in aging or frail individuals. Likewise, the average difference of -1 pound of bone mass between Styku and DEXA is clinically relevant due to the difficulty of increasing and maintaining bone mass with age, which has direct implications on health and wellness in late life. Contrary to Pearson and intraclass correlation analyses, the Bland-Altman and linear regression analyses of body composition outcomes in this study reinforce the need for additional research and refining of Styku software.

State Body Image Outcomes

To assess potential change in state body image outcomes, the State Social Physique Anxiety Scale (S-SPAS) and Body Image States Scale (BISS) were administered before body composition measurements, and once again after results were shown to study participants. A paired samples t-test revealed no significant change in S-SPAS scores for the whole sample from pretest to posttest (p = 0.08). Although non-significant, posttest scores on the S-SPAS were higher than pretest scores, which means that participants demonstrated an unfavorable shift in state social physique anxiety that was characterized by a small effect size (Cohen's d = -0.15). Because of the relatively small sample size (n = 35), the sample did not provide adequate power to detect change within sexes, BMI class, or other baseline characteristics. To date, relatively little research has been conducted to evaluate changes in state body image-related anxiety using the S-SPAS. Future research should validate the S-SPAS in male samples and utilize a similar research design as the present study with a larger sample size to see potential change and baseline characteristic mediation effects. Additionally, systematic inquiry focusing upon the effects of acute exercise on state body image outcomes, such as S-SPAS, similar to the work done by Focht and Hausenblas (2003) is warranted.

A paired samples t-test revealed a significant decrease in Body Image States Scale (BISS) scores (p = 0.03, Cohen's d = 0.31) from pretest to posttest for the entire sample. This means that after viewing the results of the body composition measurements participants, on average, had worse state body image perception than they did prior to the measurements. Outside of multi-day, repeated measures on women's body image perception using the BISS (Rudiger et al., 2007), evidence tracking potential change over a short period of time, as was done in the present study, remains limited. Because the period of time between pretest questionnaires and posttest questionnaires was short (approximately 20 minutes), it is unclear if the BISS questionnaire is sensitive to capturing meaningful change over such a limited time span. However, researchers have used the BISS questionnaire in applied settings, specifically utilizing it to track body image perception before and after a 24-hour dietary fast and saw non-significant improvements in body image perception following the fast (Schaumberg & Anderson, 2014). Despite its focus on changes in eating behaviors over 24 hours, this study shows the feasibility of measuring body image perception in applied settings. Clearly, more research is required in applied measurement settings, especially those with short measurement timelines, is needed to examine the replicability and veracity of these conclusions.

The body image results in this study are similar to those of McLester et al. (2018), who observed no significant difference in appearance satisfaction before and after body composition analysis in men alone but did see significant decreases in satisfaction among women. The appearance satisfaction questionnaire used in this study was not validated or detailed in the publication, which limits the generalizability of the results. Further, the present study is not powered to detect change stratified by sex, so more research is required on larger samples utilizing validated body image questionnaires.

Taken together, the present analyses yielded unfavorable shifts in state body image outcomes that were of small effect size in magnitude. These results should inform researchers and practitioners who measure body composition. In relation to health and psychosocial outcomes, acute body composition measurement can have deleterious effects on body image and anxiety. From a translational perspective, practitioners should ensure that individuals are not mentally or emotionally burdened through the reporting of their body composition. Additional research should focus on how acute body composition measurement and state anxiety impacts long-term health behaviors, physical and mental health status, and best practices for reporting body composition results to clients.

Strengths

A strength of this study is that it addresses a critical need for accessible and affordable body composition measurement. As stated, the Styku S100 is portable and more affordable than a DEXA machine, thus implying the importance of the Styku's validity against the present-day gold standard, DEXA. Another strength lies within assessing changes state body image perception as a result of viewing body composition results. A study with this design has been attempted only a handful of times previously. The present study serves to expand on that body of literature and offer new insights for future research in state body image perception, specifically.

Limitations

A limitation of the present study includes its small sample size. An a priori power analysis showed that a sample size of 30 had adequate power to detect statistical significance. However, a larger sample size would have increased that power and, thus, the confidence in the results drawn from this study. Future studies investigating the validity of body composition devices should draw a larger sample.

Similarly, future studies should focus on recruiting heterogeneous samples, so that results can be generalized to the larger population. The present study included a convenience sample of university students and employees, which is not the most representative sample of the population. Additional studies should look at underrepresented samples, specifically. Both the Styku and DEXA have specialized formulas and estimation equations for different races and ethnicities. Recruiting larger samples, or focusing recruitment on racial/ethnic minorities, could allow researchers to conduct sub-group analyses based on race/ethnicity to investigate whether or not the Styku differs in its validity depending on these demographic factors.

Although the study is novel in its approach to measuring body image perception before and after body composition measurement, there is an inherent limitation in the design due to the primary aim of assessing the validity of the Styku, which necessitates two body composition measurements. Because participants viewed results from both the Styku and DEXA, regardless of their level of agreement for each individual, it is unclear whether a single scan or both scans had an effect on body image perception. Future studies should take this into consideration, and perhaps present results from the criterion measure prior to collecting post-scan body image questionnaires.

Conclusion

Overall, this investigation into the validity of body composition measurement devices and changes in body image perception as a result of measuring body composition represents an important examination of the Styku and a novel approach to measuring body image. Future studies should look at refining the research methods and expanding upon demographic factors related to body composition and image perception.

References

American College of Sports Medicine. (2014). Body composition status and assessment. In D.P. Swain (Ed.), *ACSM's resource manual for guidelines for exercise testing and prescription, Seventh edition* (pp. 287-308). Wolters Kluwer Health.

American College of Sports Medicine. (2022). Health-related physical fitness testing. In G. Liguori (Ed.), *ACSM's guidelines for exercise testing and prescription, Eleventh edition* (pp. 58-112). Wolters Kluwer.

Becker, C.B., Verzijl, C.L., Kilpela, L.S., Wilfred, S.A., & Stewart, T. (2019). Body image in adult women: Associations with health behaviors, quality of life, and functional impairment. *Journal of Health Psychology, 24*(11): 1536-1547. doi: 10.1177/1359105317710815

Bennett, J.P., Liu, Y.E., Quon, B.K., Kelly, N.N., Wong, M.C., Kennedy, S.F., Chow, D.C., Garber, A.K., Weiss, E.J., Heymsfield, S.B., & Shepherd, J.A. (2022). Assessment of clinical measures of total and regional body composition from a commercial 3-dimensional optical body scanner. *Clinical Nutrition, 4*: 211-218. doi: 10.1016/j.clnu.2021.11.031

Bennett, K.J., Olatosi, B., & Probst, J.C. (2008). Health disparities: A rural-urban chartbook. *Rural Health Research & Policy Centers, South Carolina Rural Health Research Center,* Columbia, p.i-28.

Bogers, R.P., Bemelmans, W.J.E, Hoogenveen, R.T., Boshuizen, H.C., Woodward, M., Knekt, P., van Dam, R.M., Hu, F.B., Visscher, T.L.S., Menotti, A., Thorpe, R.J. Jr., Jamrozik, K., Calling, S., Strand, B.H., & Shipley, M.J. (2007). Association of overweight with increased risk of coronary heart disease partly independent of blood pressure and cholesterol levels: A Meta-analysis of 21 cohort studies including more than 300,000 persons. *Archives of Internal Medicine*, *167*(16): 1720-1728. doi: 10.1001/archinte.167.16.1720

Bourgeois, B., Ng, B.K., Latimer, D., Stannard, C.R., Romeo, L., Li, X., Shephard, J.A., & Heymsfield, S.B. (2017). Clinically applicable optical imaging technology for body size and shape analysis: Comparison of systems differing in design. *European Journal of Clinical Nutrition, 71*(11), 1329-1335. doi: 10.1038/ejcn.2017.142

Cabre, H.E., Blue, M.N.M., Hirsch, K.R., Brewer, G.J., Gould, L.M., Nelson, A.G., & Smith-Ryan, A.E. (2020). Validity of a 3-dimensional body scanner: Comparison against a 4-compartment model and dual energy x-ray absorptiometry. *Applied Physiology, Nutrition, and Metabolism, 46*(6): 644-650. doi: 10.1139/apnm-2020-0744

Calle, E.E, & Kaaks, R. (2004). Overweight, obesity and cancer: Epidemiological evidence and proposed mechanisms. *Nature Reviews Cancer, 4*: 579-591. doi: 10.1038/nrc1408

Cash, T.F., Fleming, E.C., Alindogan, J., Steadman, L., & Whitehead, A. (2002). Beyond body image as a trait: The Development and validation of the Body Image States Scale. *Eating Disorders, 10*: 103-113. doi: 10.1080/10640260290081678

Cash, T.F. (2004). Body image: Past, present, and future. *Body Image, 1*:1-5. doi: 10.1016/S1740-1445(03)00011-1

Ceniccola, G.D., Castro, M.G., Piovacari, S.M.F., Horie, L.M., Corrêa, F.G., Barrere, A.P.N., & Toledo, D.O. (2019). Current technologies in body composition assessment: Advantages and disadvantages. *Nutrition, 62*: 25-31. doi: 10.1016/j.nnut.2018.11.028

Cesani, M.F., Garraza, M., Sanchís, M.L.B., Luis, M.A., Torres, M.F., Quintero, F.A., & Oyhenart, E.E. (2013). A comparative study on nutritional status and body composition of urban and rural schoolchildren from Brandsen district (Argentina). *PloS ONE, 8*(1): e52792. doi: 10.1371/journal.pone.0052792

Chaplow, Z.L., Focht, B.C., Lucas, A.R., Grainger, E., Simpson, C., Buell, J., Fairman, C.M., Thomas-Ahner, J.M., Bowman, J., DeScenza, V.R., Monk, J.P., Mortazavi, A., & Clinton, S.K. (2020). Effects of a lifestyle intervention on body composition in prostate cancer patients on androgen deprivation therapy. *JCSM Clinical Reports, 5*(2):52-60. doi: 10.1002/crt2.13

Coutinho, T., Goel, K., Corrêa de Sá, D., Carter, R.E., Hodge, D.O., Kragelund, C., Kanaya, A.M., Zeller, M., Park, J.S., Kober, L., Torp-Pedersen, C., Cottin, Y., Lorgis, L., Lee, S.H., Kim, Y.J., Thomas, R., Roger, V.L., Somers, V.K., Lopez-Jimenez, F. (2013). Combining body mass index with measures of central obesity in the assessment of mortality in subjects with coronary disease: Role of "normal weight central obesity." *Journal of the American College of Cardiology, 61*(5):553-560. doi: 10.1016/j.jacc.2012.10.035

Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F., & Oja, P. (2003). International physical activity questionnaire: 12-Country reliability and validity. *Medicine & Science in Sports & Exercise, 35*(8): 1381-1395. doi: 10.1249/01.MSS.0000078924.61453.FB

Danielsen, K.K., Svendsen, M. Mæhlum, S., & Sundgot-Borgen, J. (2013). Changes in body composition, cardiovascular disease risk factors, and eating behavior after an intensive lifestyle intervention with high volume of physical activity in severely obese subjects: A Prospective clinical controlled trial. *Journal of Obesity, 2013*: 325464. doi: 10.1155/2013/325464

Draper, C.E., Tomaz, S.A., Stone, M.., Hinkley, T., Jones, R.A., Louw, J., Twine, R., Kahn, K., & Norris, S.A. (2017). Developing intervention strategies to optimize body composition in early childhood in South Africa. *BioMed Research International, 2017*: 5283457. doi: 10.1155/2017/5283457

Duren, D.L., Sherwood, R.J., Czerwinski, S.A., Lee, M., Choh, A.C., Siervogel, R.M., & Chumlea, W.C. (2008). Body composition methods: Comparisons and interpretation. *Journal of Diabetes Science and Technology, 2*(6):1139-1146. doi: 10.177/193229680800200623

Endler, N.S., & Kocovski, N.L. (2001). State and trait anxiety revisited. *Journal of Anxiety Disorders, 15*(3), 231-245. doi: 10.1016/s0887-615(01)00060-3

Feng, Y., Hong, X., Li, Z., Zhang, W., Jin, D., Liu, X., Zhang, Y., Hu, F.B., Wei, L.J., Zhang, T., Xu, X., & Xu, X. (2012). Prevalence of metabolic syndrome and its relation to body composition in a Chinese rural population. *Obesity, 14*(11): 2089-2098. doi: 10.1038/oby.2006.244

Focht, B.C., & Hausenblas, H.A. (2003). State anxiety responses to acute exercise in women with high social physique anxiety. *Journal of Sport & Exercise Psychology, 25*(2): 123-144. doi: 10.1123/jsep.25.123

Focht, B.C., & Hausenblas, H.A. (2006). Exercising in public and private environments: Effects on feeling states in women with social physique anxiety. *Journal of Applied Biobehavioral Research, 11*(3-4): 147-165. doi: 10.1111/j.1751-9861.2007.00002.x

Focht, B.C., Rejeski, W.J., Hackshaw, K., Ambrosius, W.T., Groessl, E., Chaplow, Z.L., DeScenza, V.R., Bowman, J. Fairman, C.M., Nesbit, B., Dispennette, K., Zhang, X., Fowler, M., Haynam, M., & Hohn, S. (2022). The collaborative lifestyle intervention program in knee osteoarthritis patients (CLIP-OA) trial: Design and methods. *Contemporary Clinical Trials*, *115*: 106730. doi: 10.1016/j.cct.2022.106730

Forbes, C.C., Yu, Z.M., Cui, Y., DeClercq, V., Grandy, S.A., Parker, L., Sweeney, E., Dummer, T.J.B., & Keats, M.R. (2019). Rural-urban disparities in total physical activity, body composition, and related health indicators: An Atlantic PATH study. *The Journal of Rural Health, 36*(1): 111-119. doi: 10.1111/jrh.12363

Gillen, M.M. (2015). Associations between positive body image and indicators of men's and women's mental and physical health. *Body Image, 13*: 67-74. doi: 10.1016/j.bodyim.2015.01.002

Gillen, M.M., & Markey, C.N. (2016). Body image and mental health. In H.S. Friedman (Eds.), *Encyclopedia of mental health* (pp.187-192). Elsevier.

Grundy, S.M. (2004). Obesity, metabolic syndrome, and cardiovascular disease. *The Journal of Clinical Endocrinology & Metabolism, 89*(6), 2595-2600. doi: 10.1210/jc.2004-0372

Harbin, M.M., Kasak, A., Ostrem, J.D., & Dengel, D.R. (2018). Validation of a three-dimensional body scanner for body composition measures. *European Journal of Clinical Nutrition, 72*: 1191-1194. doi: 10.1038/s41430-017-0046-1

Hart, E.A., Leary, M.R., & Rejeski, W.J. (1989). The measurement of social physique anxiety. *Journal of Sport & Exercise Psychology, 11*(1): 94-104. doi: 10.1123/jsep.11.1.94

Haverkort, E.B., Reijven, P.L.M., Binnekade, J.M., de van der Schueren, M.A.E., Earthman, C.P., Gouma, D.J., & de Haan, R.J. (2015). Bioelectrical impedance analysis to estimate body composition in surgical and oncological patients: A Systematic review. *European Journal of Clinical Nutrition, 69*(1): 3-13. doi: 10.1038/ejcn.2014.203

Heymsfield, S.B., Ebbeling, C.B., Zheng, J., Pietrobelli, A., Strauss, B.J., Silva, A.M., & Ludwig, D.S. (2015). Multi-component molecular-level body composition reference methods: Evolving concepts and future directions. *Obesity Reviews, 16*(4): 282-294. doi: 10.1111/obr.12261

Heymsfield, S.B., Bourgeois, B., Ng, B.K., Sommer, M.J., Li, X., & Shepherd, J.A. (2018). Digital anthropometry: A Critical review. *European Journal of Clinical Nutrition, 72*(5), 680-687. doi: 10.1038/s41430-018-0145-7

Hillier, S.E., Beck, L., Petropoulou, & Clegg, M.E. (2014). A comparison of body composition measurement techniques. *Journal of Human Nutrition and Dietetics, 27*(6): 626-631. doi: 10.1111/jhn.12197

Horne, J.R., Gilliland, J.A., O'Connor, C.P., Seabrook, J.A., & Madill, J. Change in weight, BMI, and body composition in a population-based intervention versus genetic-based intervention: The NOW trial. *Obesity, 28*(8): 1419-1427. doi: 10.1002/oby.22880

Hu, F.B. (2008). *Obesity epidemiology*. Oxford University Press. doi.10.1093/acprof:oso/9780195312911.001.0001

Jackson, A.S., Ellis, K.J., McFarlin, B.K., Sailors, M.H., & Bray, M.S. (2009). Cross-validation of generalised body composition equations with diverse young men and women: The Training intervention and genetics of exercise response (TIGER) study. *British Journal of Nutrition, 101*(6): 871-878. doi: 10.1017/S0007114508047764

Janssen, I., Miller, E., Dzongowski, E., Miakisheva, K., & Ross, R. A compositional analysis study of body composition and cardiometabolic risk factors. *Obesity, 30*: 1699-1707. doi: 10.1002/oby.23477

Koo, T.K, & Li, M.Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2): 155-163. doi: 10.1016/j/jcm.2016.02.012

Krauss, R.M., Winston, M., Fletcher, B.J., & Grundy, S.M. (1998). Obesity: Impact on cardiovascular disease. *Circulation, 98*(14), 1472-1476. doi:10.1161/01/CIR.98.14.1472

Lamarche, L., Gammage, K.L., & Gabriel, D.A. (2011). The effects of experimenter gender on state social physique anxiety and strength in a testing environment. *Journal of Strength and Conditioning Research, 25*(2): 533-538. doi: 10.1519/JSC.0b013e3181c1f7b3

Manson, J.E., Bassuk, S.S., Hu, F.B., Stampfer, M.J., Colditz, G.A., & Willet, W.C. (2007). Estimating the number of deaths due to obesity: Can the divergent findings be reconciled? *Journal of Women's Health, 16*(2): 168-172. doi: 10.1089/jwh.2006.0080

Martin-Ginis, K.A., Bassett-Gunter, R.L., & Conlin, C. (2012). Body image an exercise. In E.O. Acevedo (Eds.), *The Oxford handbook of exercise psychology* (pp.55-75). Oxford University Press.

Martin-Ginis, K.A., Murru, E., Conlin, C., & Strong, H.A. (2010). Construct validation of a state version of the Social Physique Anxiety Scale among young women. *Body Image, 8*: 52-57. doi: 10.1016/j.bodyim.2010.10.001

McLester, C.N., Hicks, C.S., Miller, L., & McLester, J.R. (2018). An investigation of the differences between perceived vs. measured body composition, social physique anxiety, and overall appearance satisfaction among college students. *International Journal of Exercise Science, 11*(5): 957-967.

Mitchell, N.S., Catenacci, V.A., Wyatt, H.R., & Hill, J.O. (2011). Obesity: Overview of an epidemic. *Psychiatric Clinics of North America, 34*(4), 717-732. doi: 10.1016/j.psc.2011.08.005

Myles, P.S., & Cui, J. (2007). I. Using the Bland-Altman method to measure agreement with repeated measures. *BJA: British Journal of Anaesthesia*, *99*(3): 390-311. doi: 10.1093/bja/aem214

Rashid, M.N., Fuentes, F., Touchon, R.C., & Wehner, P.S. (2007). Obesity and the risk for cardiovascular disease. *Preventive Cardiology, 6*(1), 42-47. doi: 10.1111/j.1520-037X.2003.01358.x

Reboussin B.A., Rejeski W.J., Martin K., Callahan K., Dunn A.L., King A.C., & Sallis, J.F. (2000). Correlates of satisfaction with body function and appearance in middle- and older aged adults: The Activity counseling trial (ACT). *Psych Health, 15*(2):239-254. doi:10.1080/08870440008400304

Rudiger, J.A., Cash, T.F., Roehrig, M., & Thompson, J.K. (2007). Day-to-day body image states: Prospective predictors of intra-individual level and variability. *Body Image, 4*: 1-9. doi: 10.1016/j.bodyim.2006.11.004

Sareen, R. (2018). Styku Phoenix: Predicting DEXA body composition using 3D full body infrared scanning. [Unpublished manuscript].

Schaumberg, K. & Anderson, D.A. (2014). Does short-term fasting promote change in state body image? *Body Image, 11*: 167-170. doi: 10.1016/j.bodyim.2014.01.005

Schober, P., Boer, C., & Schwarte, L.A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesthesia & Analgesia, 126*(5): 1763-1768. doi: 10.1213/ANE. 0000000000002864

Shroff, H.P., Calogero, R.M., & Thompson, J.K. (2009). Assessment of body image. In D.B. Allison & M.L. Baskin (Eds.), *Handbook of assessment methods for eating behaviors and weight-related problems: Measures, theory, and research* (pp. 115-136). Sage Publications.

Smith, L.H., Petosa, R.L., & Laurent, D. (2019). Efficacy of “Mentoring to Be Active” on weight loss, body mass index, and body fat among obese and extremely obese youth in rural Appalachia. *The Journal of Rural Health, 36*(1): 77-87. doi: 10.1111/jrh.12410

Tan, M., Brown, L.J., Matthews, K.I., Whatnall, M.C., Hutchesson, M.J., MacDonald-Wicks, L.K., & Patterson, A.J. (2019). Rural versus urban women: An Examination of anthropometry and body composition. *Australian Journal of Rural Health, 27*(1): 70-77. doi: 10.1111/ajr.12466

Tanamas, S.K., Lean, M.E.J., Combet, E., Vlassopoulos, A., Zimmet, P.Z., & Peeters, A. (2016). Changing guards: Time to move beyond body mass index for population monitoring of excess adiposity. *QJM: An International Journal of Medicine, 109*(7): 443-446. doi: 10.1093/qjmed/hcv201

Tchernof, A. & Després, J.P. (2013). Pathophysiology of human visceral obesity: An Update. *Physiological Reviews, 93*(1): 359-404. doi: 10.1152/physrev.0003.2011

Tewari, N., Awad, S., Macdonald, I.A., & Lobo, D.N. (2017). A comparison of three methods to assess body composition. *Nutrition*, *47*: 1-5. doi: 10.1016/j.nut.2017.09.005

Tinsley, G.M., Moore, M.L., Dellinger, J.R., Adamson, B.T., & Benavides, M.L. (2020). Digital anthropometry via three-dimensional optical scanning: Evaluation of four commercially available systems. *European Journal of Clinical Nutrition*, *74*(7), 1054-1064. doi: 10.1038/s41430-019-0526-6

Tran, Z.V, & Weltman, A. (1989). Generalized equation for predicting body density of women from girth measurements. *Medicine & Science in Sports & Exercise, 21*(1):101-104. doi: 10.1249/00005768-198902000-00018

Tran, Z.V., & Weltman, A. (1988). Predicting body composition of men from girth measurements. *Human Biology, 60*(1), 17, 167-175.

United States Centers for Disease Control and Prevention. (2021, September 30). *Adult obesity facts*. CDC. https://www.cdc.gov/obesity/data/adult.html

University of California Davis Sports Medicine. (2023). *Body composition.* UC Davis Health. https://health.ucdavis.edu/sports-medicine/resources/body-fat#:~:text=With%20respect%20to%20health%20and,very%20helpful%20in%20assessing%20health.

VanSumeren, M., Weber, S., Civelek, J., Sabourinn, J., Smith-Hale, V., & Hew-Butler, T. (2022). Longitudinal changes in fat and lean mass: Comparisons between 3D-infrared and dual-energy x-ray absorptiometry scans in athletes. *International Journal of Exercise Science, 15*(4): 1587-1599.

Wilson, R.E., Latner, J.D., & Hayashi, K. (2013). More than just body weight: The role of body image in psychosocial and physical functioning. *Body Image*, *10*: 644-647. doi: 10.1016/j.bodyim.2013.04.007

Xu, L., Cheng, X., Wang, J., Cao, Q., Sato, T., Wang, M., Zhao, X., & Liang, W. (2011). Comparisons of body-composition prediction accuracy: A Study of 2 bioelectric impedance consumer devices in healthy Chinese persons using DXA and MRI as criteria methods. *Journal of Clinical Densitometry*, *14*(4): 458-464. doi: 10.1016/j.jocd.2011.04.001

Zhang, C., Rexrode, K.M., van Dam, R.M., Li, T.Y., & Hu, F.B. (2008). Abdominal obesity and the risk of all-cause, cardiovascular, and cancer mortality: Sixteen years of follow-up in US women. *Circulation, 117*(13): 1658-1667. doi: 10.1161/CIRCULATIONAHA.107.73971

Appendix A. Tables

Method	**Standard Error of Estimation**
Circumferences	$\pm$ 2.5 – 4.0%
Skinfolds	$\pm$ 3.5%
Bioelectrical Impedance Analysis (BIA)	$\pm$ 3.5 – 5.0%
Hydrodensitometry/Underwater Weighing	$\pm$ 2.5%
Air Displacement Plethysmography (ADP)	$\pm$ 2.2 – 3.7%
Dual-Energy X-Ray Absorptiometry (DEXA)	$\pm$ 1.8%

Table 1. Body Composition Methods - Standard Error of Estimation (SEE)

Item	**Domain**
1	Dissatisfaction-Satisfaction with one’s overall appearance
2	Dissatisfaction-Satisfaction with one’s size and shape
3	Dissatisfaction-Satisfaction with one’s weight
4	Feelings of physical attractiveness-unattractiveness
5	Current feelings about one’s looks relative to how one usually feels
6	Evaluation of one’s appearance relative to how the average person looks

Table 2. Body Image States Scale Domains

Tests & Observations	Pre-Test	Test	Post-Test
Signed informed consent	x		
Demographic Questionnaire/Pre-Screening	x		
Pregnancy Test for Females	x		
Height/Weight	x		
IPAQ Questionnaire	x		
SFA Questionnaire	x		
S-SPAS Questionnaire	x		x
BISS Questionnaire	x		x
Styku and DEXA Scan		x	

Table 3. Outline of Study Measures

Characteristic	N (n = 35)	%
Sex		
Female	20	57.1
Male	15	42.9
Ethnicity		
Caucasian	28	80.0
Far East Asian	3	8.6
Hispanic or Latin American	2	5.7
Indian Subcontinent	1	2.9
Native Hawaiian or Other Pacific Islander	1	2.9
Education Level		
High School/GED	10	28.6
Bachelor’s	10	28.6
Master’s	13	37.1
Doctoral	1	2.9
Professional	1	2.9
Employment		
Full-Time	12	34.3
Part-Time	15	42.9
Not Employed/Retired	8	22.9
Student Status		
Full-Time	20	57.1
Part-Time	0	0
Not a Student	15	42.9
BMI		
< 18 kg/m^2	0	0
18 – 25 kg/m^2	15	42.8
25 – 30 kg/m^2	17	48.6
> 30 kg/m^2	3	8.6

Table 4. Demographic Characteristics

Sex		Styku Body Mass	DEXA Body Mass	Styku Body Fat %	DEXA Body Fat %	Styku Fat Mass	DEXA Fat Mass	Styku Lean Mass %	DEXA Lean Mass %	Styku Lean Mass	DEXA Lean Mass	Styku Bone Mass	DEXA Bone Mass
Female	*M*	144.100	144.680	32.915	31.295	48.015	44.020	63.795	66.035	91.820	95.085	4.710	5.590
n = 20	*SD*	19.034	18.597	3.558	5.936	10.232	12.293	3.335	5.527	9.492	10.931	0.392	0.789
Male	*M*	187.930	186.514	21.014	18.487	39.793	33.108	75.657	78.246	141.900	145.990	6.229	7.423
n = 15	*SD*	27.331	29.360	3.371	5.221	9.852	10.895	3.179	4.899	19.528	25.061	0.650	1.443
Total	*M*	162.150	162.609	28.015	25.806	44.629	39.343	68.679	71.268	112.441	116.901	5.335	6.375
n = 35	*SD*	31.341	31.455	6.864	8.502	10.742	12.781	6.745	8.034	28.775	31.283	0.911	1.432

Table 5. Body Composition Descriptive Statistics

Measure	1	2	3	4	5	6	7	8	9	10	11	12
1.Styku Body Mass	--											
2. DEXA Body Mass	.998**	--										
3. Styku Body Fat %	-.419*	-.426*	--									
4. DEXA Body Fat %	-.426*	-.402*	.839**	--								
5. Styku Fat Mass	.297	.288	.736**	.579**	--							
6. DEXA Fat Mass	.104	.116	.666**	.851**	.802**	--						
7. Styku Lean Mass %	.443**	.450**	-1.000**	-.839**	-.718**	-.652**	--					
8. DEXA Lean Mass %	.432*	.408*	-.839**	-.999**	-.572**	-.846**	.838**	--				
9. Styku Lean Mass	.939**	.943**	-.699**	-.647**	-.045	-.172	.718**	.652**	--			
10. DEXA Lean Mass	.917**	.919**	-.665**	-.727**	-.033	-.285	.683**	.731**	.971**	--		
11. Styku Bone Mass	.921**	.924**	-.690**	-.679**	-.048	-.220	.705**	.684**	.980**	.970**	--	
12. DEXA Bone Mass	.869**	.863**	-.548**	-.549**	.049	-.130	.565**	.538**	.883**	.875**	.891**	--

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 6. Body Composition Bivariate Correlations

Control	Measure	1	2	3	4	5	6	7	8	9	10	11	12
Sex	1.Styku Body Mass	--											
	2. DEXA Body Mass	.997**	--										
	3. Styku Body Fat %	.522**	.533**	--									
	4. DEXA Body Fat %	.202	.202	.579**	--								
	5. Styku Fat Mass	.853**	.857**	.877**	.477**	--							
	6. DEXA Fat Mass	.588**	.586**	.695**	.895**	.766**	--						
	7. Styku Lean Mass %	-.500**	-.512**	-.999**	-.575**	-.865**	-.683**	--					
	8. DEXA Lean Mass %	-.201	-.199	-.566**	-.999**	-.468**	-.892**	.561**	--				
	9. Styku Lean Mass	.939**	.939**	.219	.009	.630**	.393*	-.194	-.011	--			
	10. DEXA Lean Mass	.847**	.854**	.217	-.325	.567**	.080	-.200	.329	.899**	--		
	11. Styku Bone Mass	.857**	.855**	.113	-.156	.529**	.227	-.098	.154	.935**	.902**	--	
	12. DEXA Bone Mass	.749**	.731**	.112	-.155	.461**	.169	-.104	.126	.800**	.768**	.796**	--

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 7. Body Composition Partial Correlations

Measure	Intraclass Correlation		
	ICC	95% Confidence Interval	*p*
Body Mass	1.000	(0.998, 1.000)	< 0.001
Body Fat%	0.889	(0.761, 0.946)	< 0.001
Fat Mass	0.847	(0.583, 0.934)	< 0.001
Lean Mass %	0.883	(0.716, 0.947)	< 0.001
Lean Mass	0.978	(0.937, 0.990)	< 0.001
Bone Mass	0.734	(-0.184, 0.917)	< 0.001

Table 8. Body Composition Intraclass Correlations

Measure	Linear Regression Analysis		
	β	*t*	*p*
Body Mass	0.020	3.964	< 0.001
Body Fat%	0.228	2.207	0.035
Fat Mass	0.179	1.540	0.133
Lean Mass %	0.185	1.774	0.086
Lean Mass	0.100	2.324	0.027
Bone Mass	0.477	5.942	< 0.001

Table 9. Body Composition Linear Regression

Sex		BISS Pre-Test	BISS Post-Test	S-SPAS Pre-Test	S-SPAS Post-Test
Female	M	36.150	33.300	2.072	2.244
n = 20	SD	7.250	8.892	0.623	0.679
Male	M	36.930	35.400	1.881	1.867
n = 15	SD	6.147	7.317	0.459	0.532
Total	M	36.490	34.200*	1.990	2.083
n = 35	SD	6.714	8.206	0.559	0.640

* Change from pre-test is significant at the 0.05 level.

Table 10. Body Image Perception Questionnaire Descriptive Statistics

Appendix B. Figures

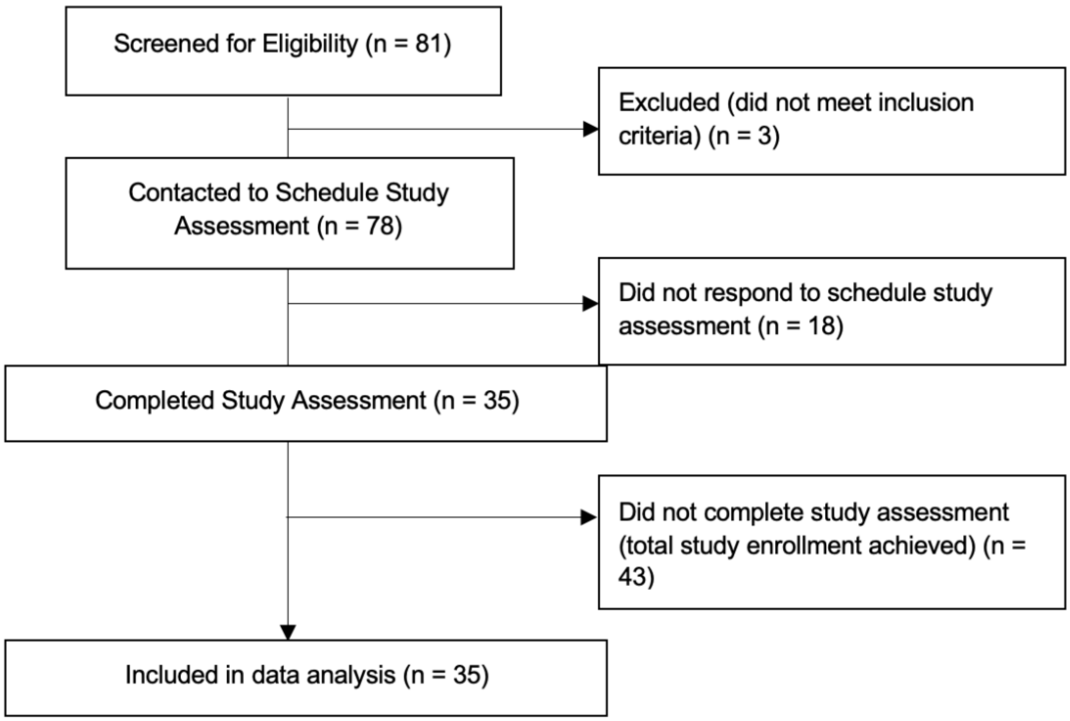

Figure 1. CONSORT Diagram

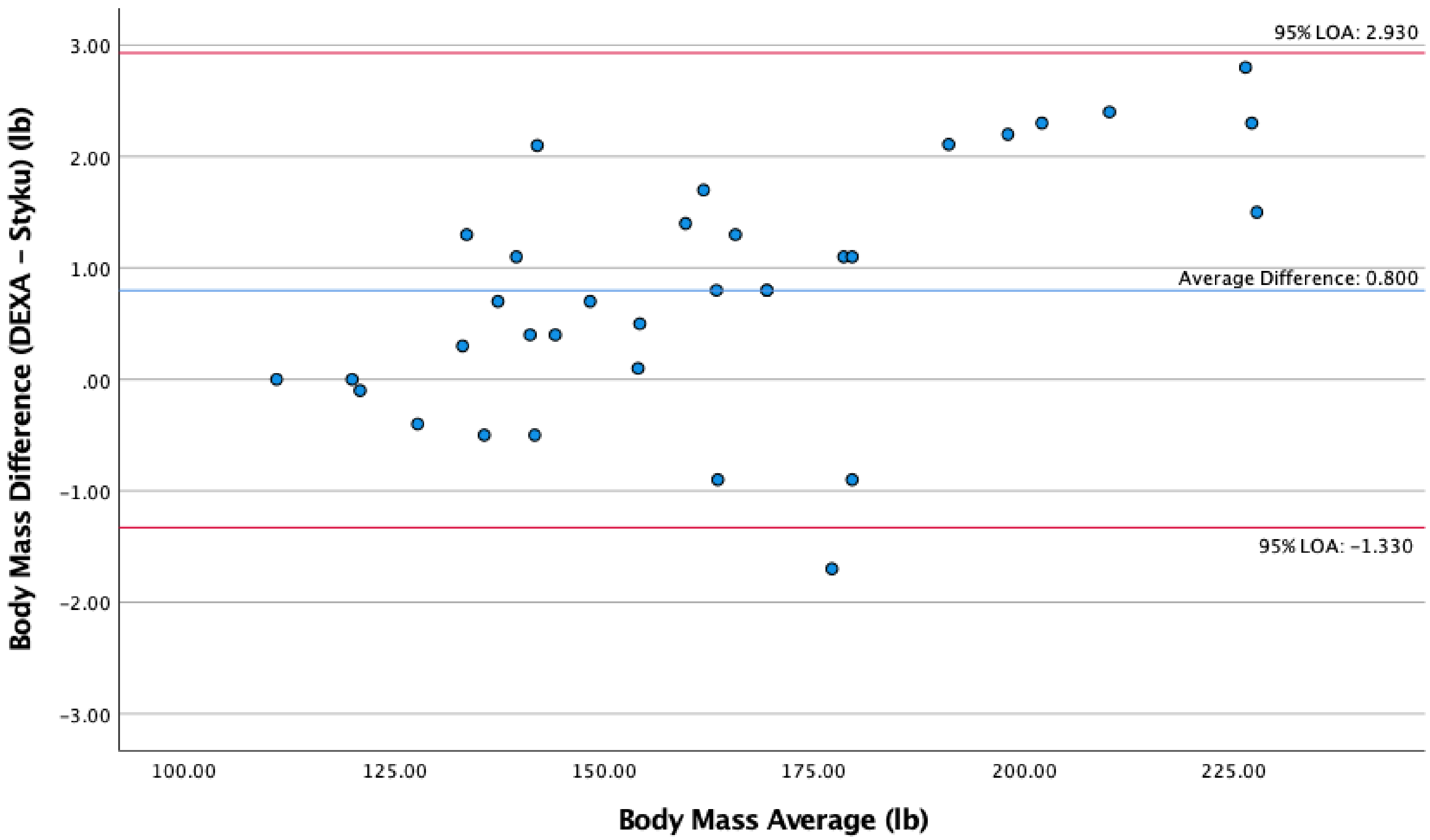

Figure 2. Bland-Altman Plot of Body Mass

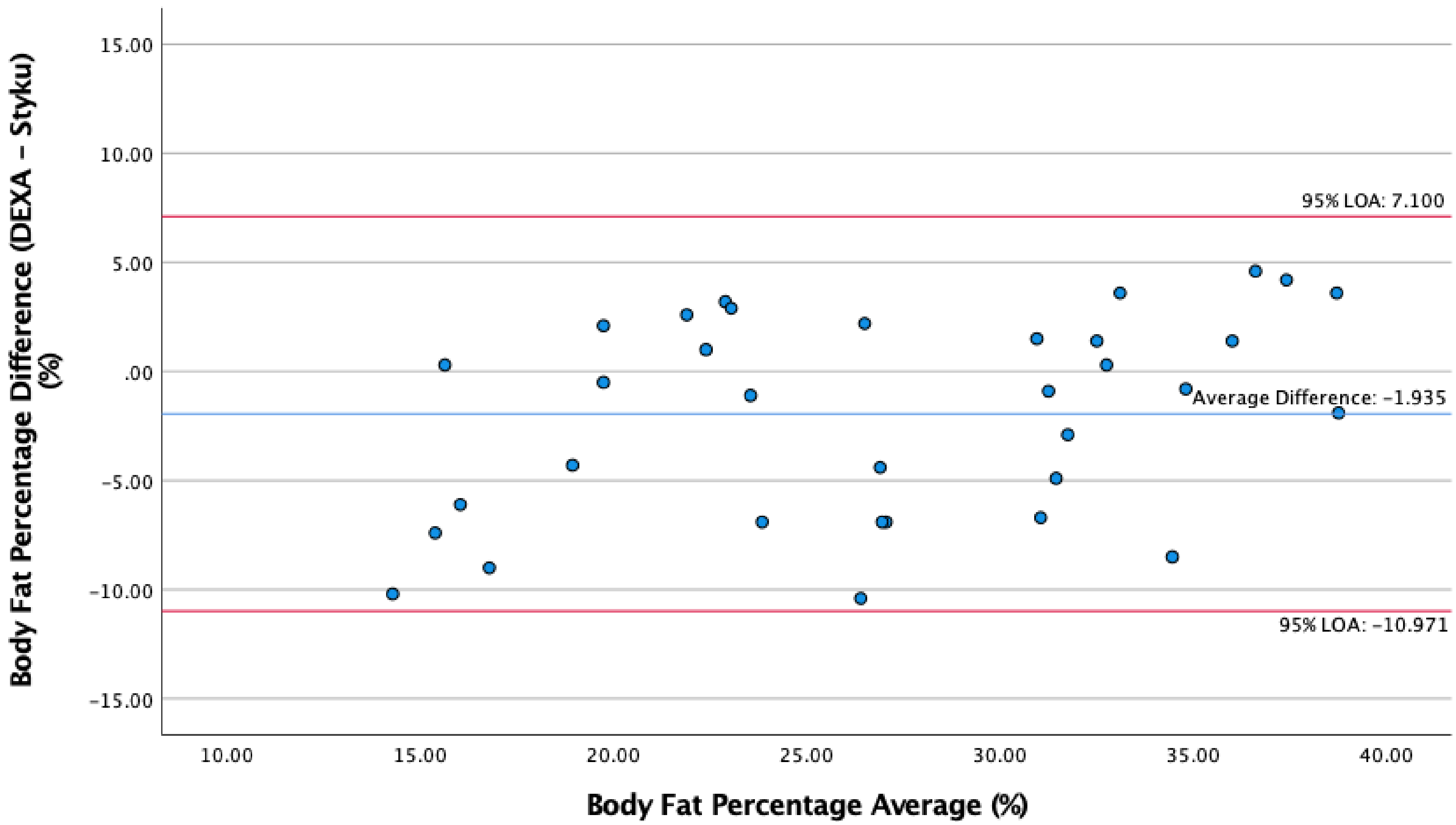

Figure 3. Bland-Altman Plot of Body Fat Percentage

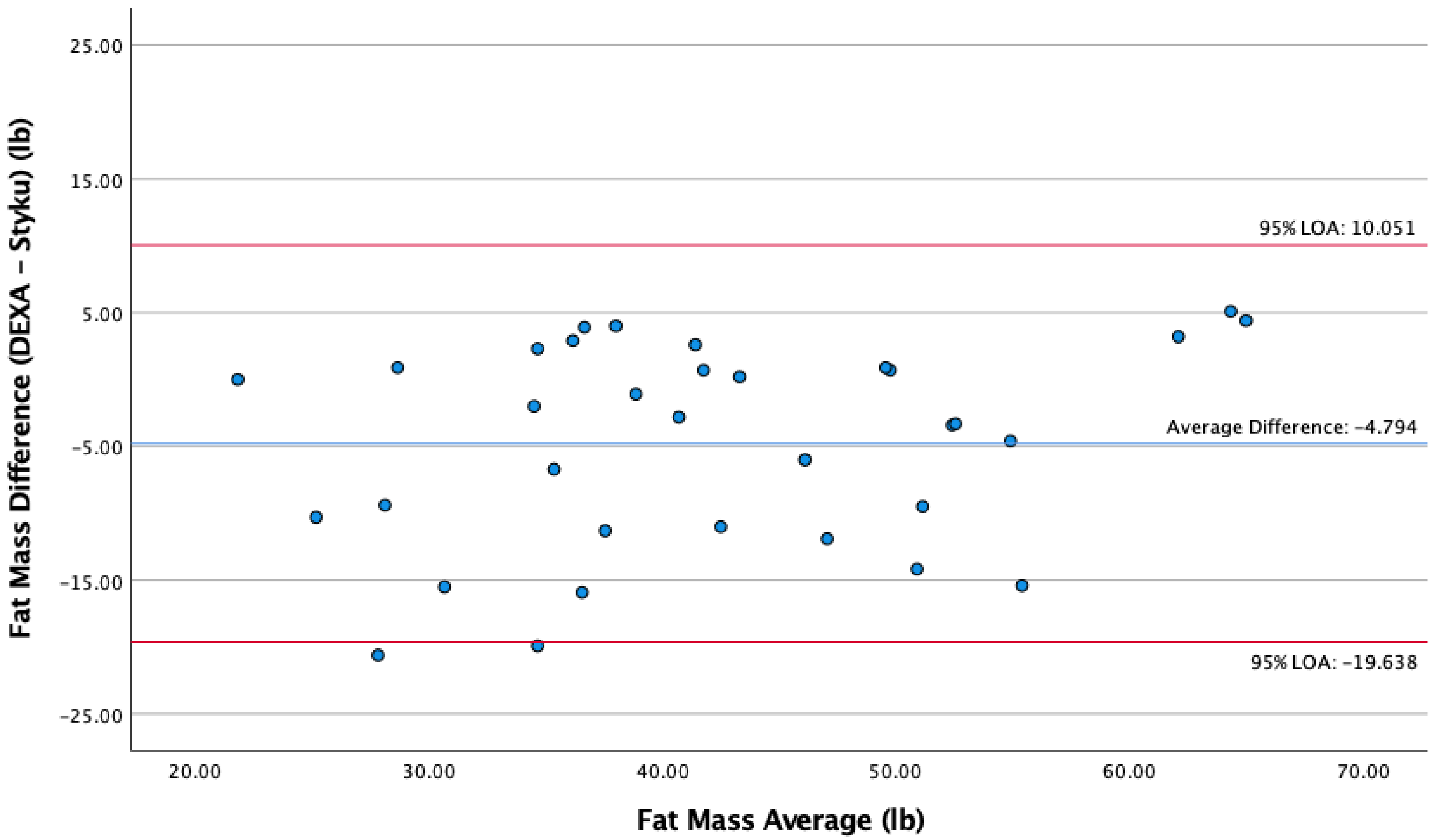

Figure 4. Bland-Altman Plot of Fat Mass

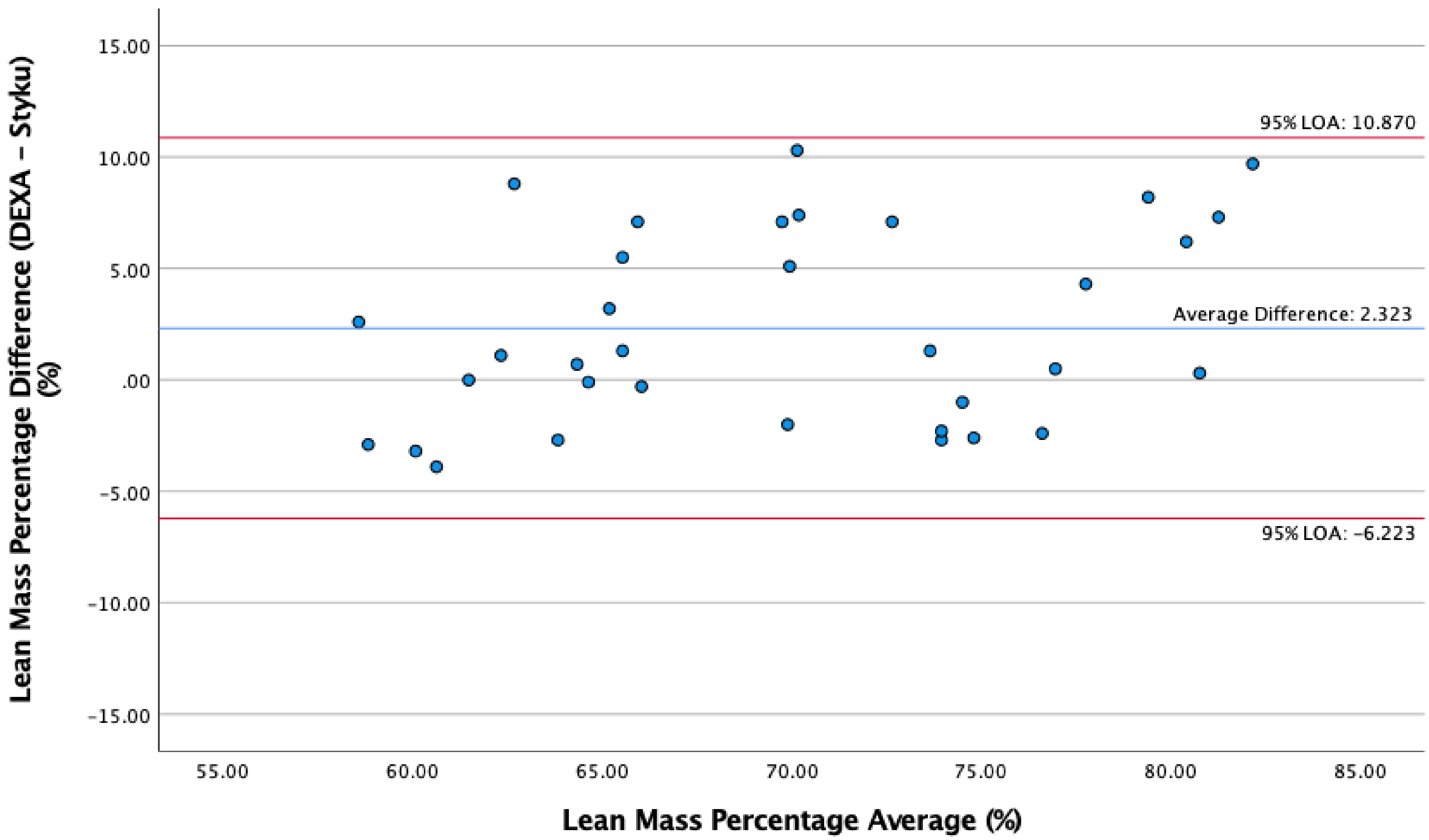

Figure 5. Bland-Altman Plot of Lean Mass Percent

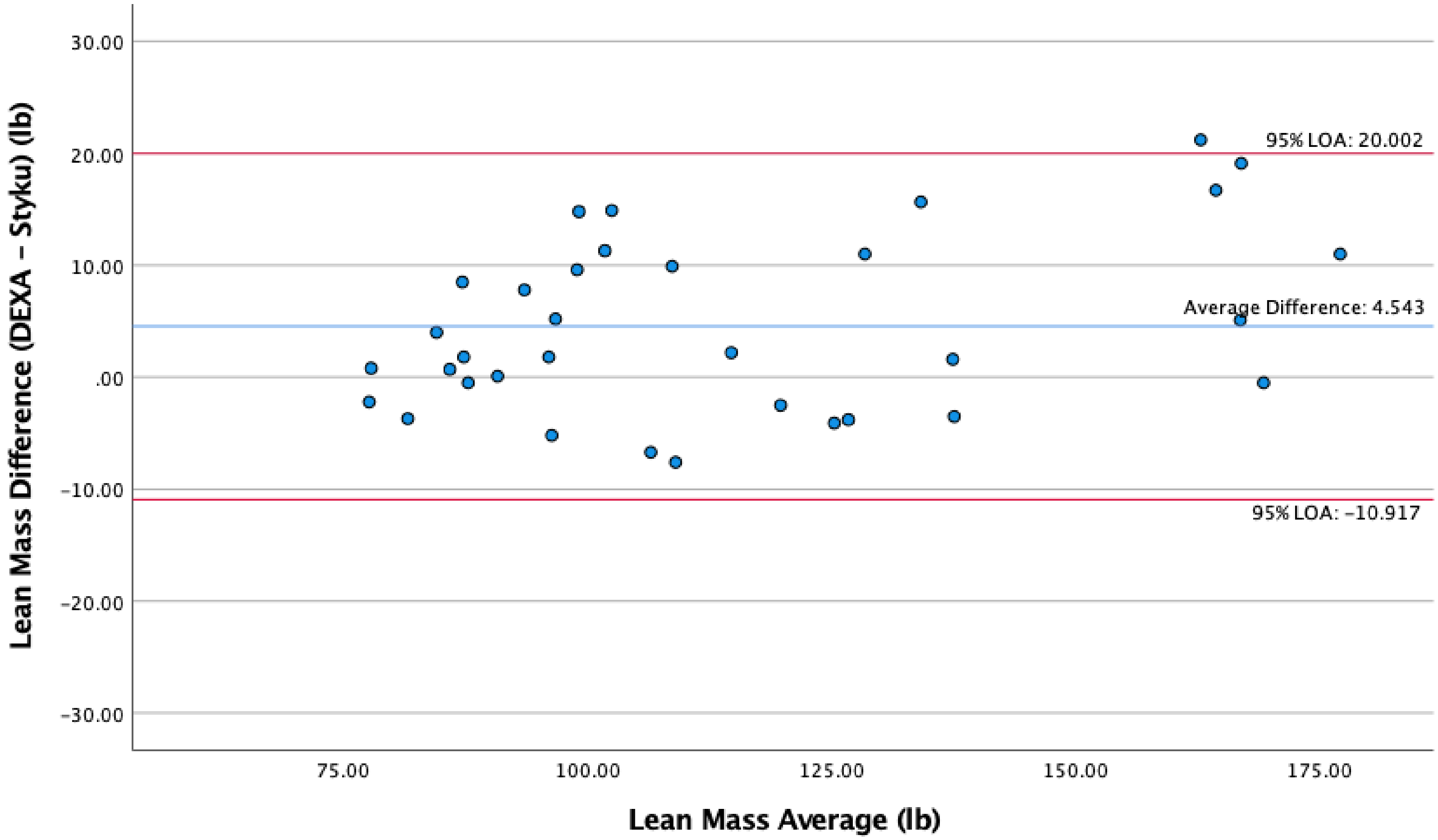

Figure 6. Bland-Altman Plot of Lean Mass

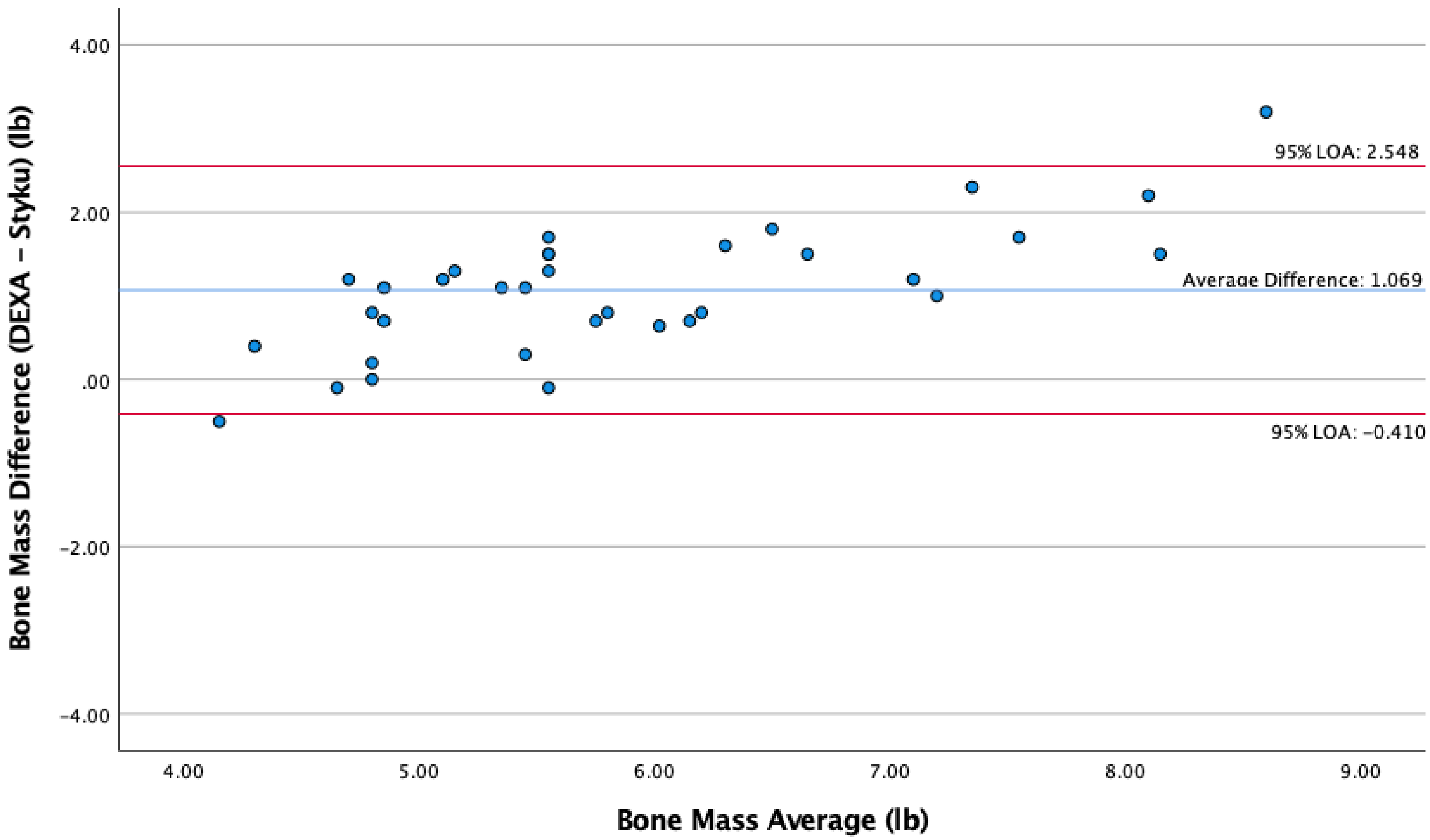

Figure 7. Bland-Altman Plot of Bone Mass