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Original Research

Reliability of a Novel Automated Ultrasound Technology for Body Composition Assessment and Comparisons with Dual Energy X-Ray Absorptiometry

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ABSTRACT

International Journal of Exercise Science 16(4): 393-401, 2023. Body composition tools vary in reliability, portability, and accessibility. The purpose of this study was to evaluate test-retest reliability of MuscleSound® (MS) and dual-energy x-ray absorptiometry (DXA) for both two compartment (region) and three compartment (tissue) models. A secondary aim was to compare body composition values produced by both devices. Fifty participants (n = 25 male, n = 25 female) aged 18-39 years completed two body composition assessments, twice in a single session. Participants arrived at the lab after a 12-hour fast. DXA required participants to lay supine for 10-15 minutes during the scanning process. Thereafter, MS was utilized to measure subcutaneous adipose tissue thickness at seven sites: chest, subscapula, triceps, axilla, suprailium, abdomen, and mid-thigh. MS automatically estimated body composition utilizing a modified Jackson-Pollock equation and the Siri equation within the software. The sequence of assessments was then repeated. Statistical analysis included paired T-tests with Pearson correlations, intraclass correlation coefficients (ICC), and least significant change (LSC). Both methods were strongly reliable (ICC_{MS} = .997, $ICC_{DXA\text{-}region}$ = .999, $ICC_{DXA\text{-}tissue}$ = .999). MS and DXA-region body fat percentages were significantly different (mean difference (%): 2.60 ± 1.32, p < .001) but highly correlated (r = .928, p < .001). Notably, the mean difference was within DXA-region's calculated least significant change of 3.24%. MS is reliable for assessing body fat percentage in young and middle-aged adults and operators can utilize MS to collect body composition data in the field.

KEY WORDS: Muscle health, sonography, body fat

INTRODUCTION

Dual-energy x-ray absorptiometry (DXA) is often utilized in body composition studies but has drawbacks when utilized in large-scale research and population-based settings. DXA measures require participants to visit a dedicated lab space of at least 144 square feet, and the financial burden of DXA can be substantial (13, 30). Proper bone densitometry certification and medical approval from a board-certified radiologist are required to perform DXA scans in many states.

Moreover, DXA scans present the risk of low-dose ionizing radiation exposure, which may be unsafe for some populations or if repeatedly exposed to ionizing radiation with other medical testing (9).

A key difference between DXA and other common body composition measures is the use of a three versus two-compartment model (10). Many body composition assessments utilize a simple two-compartment structure: fat and fat-free mass. DXA measures absorption levels of two different x-ray beams which detect fat versus fat-free mass and bone versus soft tissue mass. DXA then computes body composition results as being three compartments: fat mass, bone mass, and lean mass (fat free mass minus bone). By isolating the DXA data comparing fat versus fat-free mass, comparisons can be made with other two-compartment models.

Diagnostic ultrasound imaging is a body composition estimation method which utilizes subcutaneous adipose tissue thickness equations (12). When captured by a trained operator, these precise measurements can be utilized in validated skinfold caliper formulas. Ultrasound imaging has a positive relationship with fat measures estimated from air displacement plethysmography testing in athletic populations (12). Traditional ultrasound imaging requires manual measurement of thickness via image analysis software which can be time-consuming and leave room for error (5, 29).

Recent advances in ultrasound imaging and mobile tablet technology have resulted in a novel body composition measurement option which is portable, cloud-based, and automatically analyzed by artificial intelligence (6, 11). MuscleSound® (MS) utilizes proprietary algorithms to analyze ultrasound images taken by a trained operator and estimate subcutaneous adipose tissue thickness. MS then produces a body composition estimate. Yet, only one study to date has compared MS to DXA measures (11). The primary purpose of this study was to evaluate test-retest reliability of body composition measures produced by MS and DXA. A secondary purpose was to compare both assessments.

METHODS

Participants

A homogenous sample of participants (n_{male} = 25, n_{female} = 25) aged 18-39 years were recruited via email listservs and word-of-mouth. Those who were pregnant, had a pacemaker, or weighed over 350 pounds were excluded due to the low dose radiation exposure during a DXA scan and the weight limit of the GE Lunar Prodigy (GE Healthcare, Madison, WI). The descriptive characteristics of the 50 participants are shown in Table 1. Written informed consent was provided by participants before engaging in our study and protocols were approved by the North Dakota State University Institutional Review Board (#IRB0003273). This investigation was conducted in accordance with the ethical standards established by the International Journal of Exercise Science (24).

Table 1. Descriptive characteristics of participants (95% confidence interval).

	Men (n = 25)	Women (n = 25)	Total (n = 50)
Age (years)	25.1 (23.4, 26.9)	23.4 (22.2, 24.6)	24.3 (23.2, 25.3)
Height (m)	1.82 (1.79, 1.85)	1.68 (1.65, 1.71)	1.75 (1.72, 1.78)
Body Mass (kg)	90.0 (83.1, 96.9)	67.0 (62.8, 71.3)	78.5 (73.4, 83.6)
BMI (kg/m^2)	27.1 (25.3, 29.0)	23.7 (22.5, 25.0)	25.4 (24.3, 26.6)
DXA (region) Body Fat (%)	20.1 (17.3, 22.8)	28.7 (26.2, 31.3)	24.4 (22.2, 26.6)
DXA (tissue) Body Fat (%)	20.9 (18.0, 23.7)	29.8 (27.2, 32.5)	25.3 (23.1, 27.6)
MS Body Fat (%)	16.6 (14.4, 18.8)	27.0 (24.8, 29.2)	21.8 (19.7, 23.9)

Notes: Kg = kilograms; m = meters; BMI = body mass index; DXA = dual-energy x-ray absorptiometry; MS = MuscleSound®

Protocol

A cross-sectional research design was utilized to compare body composition measures measured by DXA (region and tissue) and MS. Several factors were controlled to best isolate body composition: time of day, 12-hours of prior nutritional intake and exercise activity, measurement order, and calibration status of measurement devices. Participants arrived at the lab the morning of data collection after fasting and refraining from exercise for 12-hours. Participants wore shorts and shirts free of metal (e.g. zippers, snaps), sports bra if applicable, and were asked to remove any jewelry, eyewear, etc. Screening for COVID-19 risk was completed upon arrival including a self-report symptom questionnaire and temporal temperature measurement. All participants passed COVID-19 screening. Additional screening for DXA included a pregnancy test for females (ClinicalGuard, Atlanta, GA). To reduce risk of COVID-19 exposure, all researchers and participants wore masks and gloves. Height and body mass (shoes removed) were recorded by researchers utilizing a stadiometer (Seca 213; Chino, CA) and digital scale (Denver Instrument DA-150; Arvada, CO). All measures were completed in the following order to control for any potential fluid shifts: DXA, MS, DXA, MS.

Each participant first underwent one DXA scan on a Lunar Prodigy, model #8915 (GE Healthcare, Madison, WI), with enCORE software (version 16). The device was calibrated according to manufacturer specifications. Scans were completed with participant hands in the mid-prone position and ankles secured by a strap (22). Participants laid still for the 10–15-minute scan. Two-compartment (region) and three-compartment (tissue) data comparing fat versus fat-free mass was utilized for DXA comparisons. Following DXA analysis, participants stood up and removed shirts in preparation for transmission gel application. MS (MuscleSound, Denver, CO) measurements were then completed in a standing position. Two researchers previously trained in sonographic techniques by the lab manager underwent additional device-specific training by the manufacturer in preparation for this study. Data were collected utilizing high-frequency B-mode ultrasound running on an Android tablet with attached Lumify L12-4 linear array transducer (Philips Healthcare, Andover, MA). Images were collected at each of the following seven sites: chest, subscapula, triceps, axilla, suprailium, abdomen, and mid-thigh (14). Both measures were repeated utilizing the same methods, after which data collection concluded. Thickness assessments consisting of skin and subcutaneous adipose tissue from the seven sites were visually verified, summed by the MS software, and utilized in a modified Jackson-Pollock seven-site skinfold equation to estimate body density (6, 15). The software then automatically entered body density in the Siri two-compartment equation to estimate body composition (27).

Statistical Analysis

All analyses were conducted with SPSS Version 28.0 (IBM; Armonk, NY). Intraclass correlation coefficients (S&F[3,k]) were analyzed between first and second values of each measure to assess reliability (26). This analysis was also applied for interrater reliability between the two researchers. The means of the first and second values for each individual measure were evaluated using paired t-tests and Pearson product-moment correlations. Least significant change (LSC) was calculated by the following equation (CV%RMS: Root-mean-squared percent coefficient of variation) (18):

LSC = CV%RMS * 2.77

Statistical significance was set at an alpha level of $p < 0.05$.

RESULTS

Strong intraclass correlation coefficients were calculated when comparing first and second values produced by each of the two assessments (Table 2). Researchers demonstrated strong interrater reliability (Cronbach's Alpha = 0.991). LSCs for DXA-region, DXA-tissue, and MS body fat percentage (i.e. the minimal absolute body fat percentage change required to be 95% confident actual change occurred) were calculated at 3.24%, 3.34%, and 4.59% respectively. Paired T-tests revealed significant differences between DXA and MS values but strong correlations (Table 3). Limits of agreement are highlighted in Figure 1 and Figure 2.

Table 2. Reliability of body composition assessments (body fat %).

Device	Cronbach's Alpha
MS	0.997*
DXA (region)	0.999*
DXA (tissue)	0.999*

Notes: DXA = dual-energy x-ray absorptiometry; MS = MuscleSound®; *$p < 0.001$.

Table 3. Paired t-tests, Pearson correlations, and mean differences between MS & DXA.

Value	*t*	Correlation (*r*)	Mean Diff	Std Deviation	Std Error
Body Fat (Region) (%)	-6.332*	0.928*	-2.60	1.32	0.41
Body Fat (Tissue) (%)	-8.447*	0.928*	-3.54	2.96	0.42
Fat Mass (kg)	-6.284*	0.942*	-2.19	2.46	0.35
Fat Free Mass (kg)	4.665*	0.987*	1.68	2.55	0.36

Notes: DXA = dual-energy x-ray absorptiometry; MS = MuscleSound®; kg = kilograms; Mean Diff = mean difference; Std Deviation = standard deviation; Std Error = standard error; *$p < 0.001$.

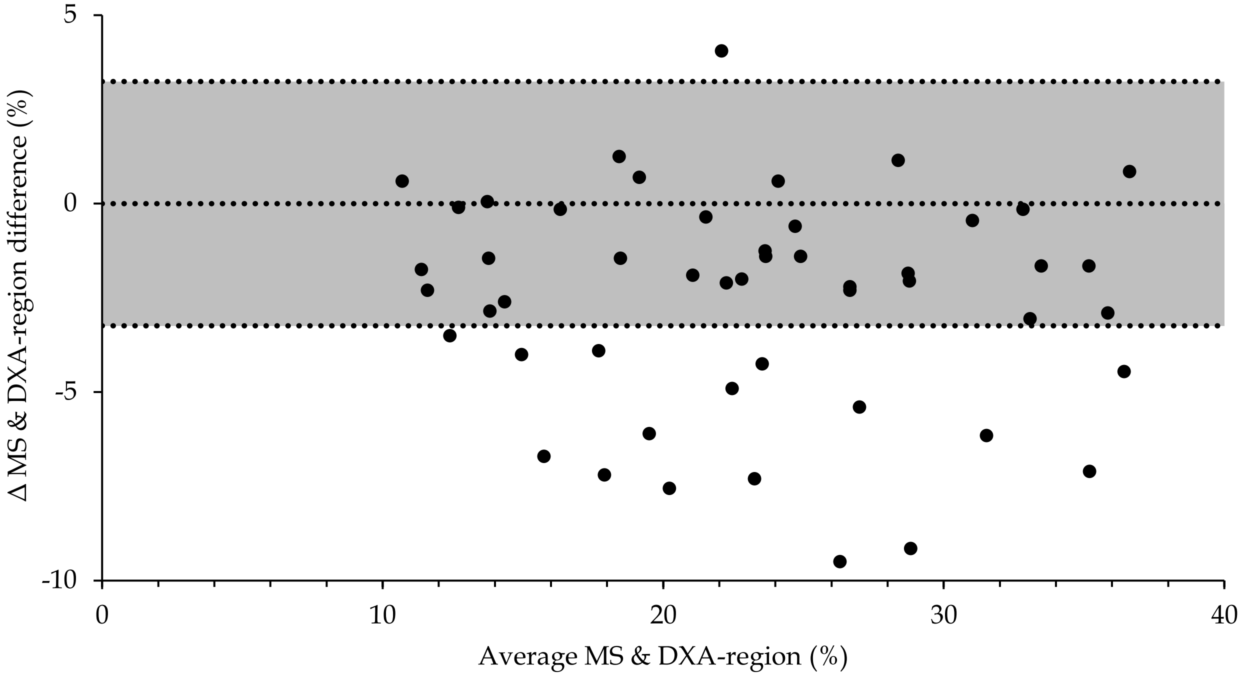

Figure 1. Body fat percentage produced by MS relative to DXA-region.
Notes: DXA = dual-energy x-ray absorptiometry; MS = MuscleSound®; y = 0 is perfect line of agreement; shaded area = DXA-region least significant change %

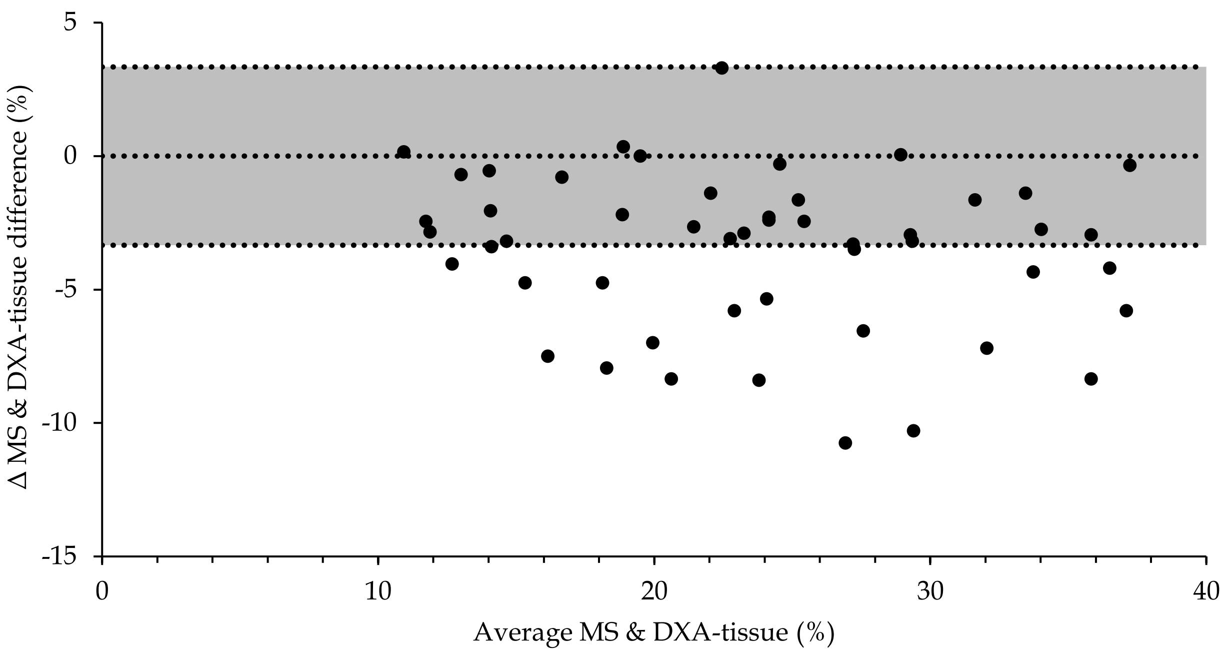

Figure 2. Body fat percentage produced by MS relative to DXA-tissue.
Notes: DXA = dual-energy x-ray absorptiometry; MS = MuscleSound®; y = 0 is perfect line of agreement; shaded area = DXA-tissue least significant change %

DISCUSSION

While MS is thought to reduce intra-rater reliability concerns typically seen in skinfold caliper testing, little has been published besides reliability data on highly skilled physicians (7). The primary finding of this study was the establishment of MS reliability. Although researchers had previous experience with ultrasonography from in-house training by the lab manager, they only completed a single in-person session and one remote follow-up session of device-specific training from the manufacturer. Despite this lack of professional experience, MS values were highly reliable. Non-clinical practitioners without formal ultrasonography training may also be able to utilize MS to reliably acquire body composition data following minimal training. According to Hyde et. al (12), MS more accurately measures subcutaneous adipose tissue thickness than skinfolds, providing a better value for the Jackson-Pollock equation. In line with previous findings, DXA was reliable (3).

Another interesting finding was related to the MS body composition comparisons versus DXA-region body composition; which should both be two-compartment models. Mean differences of body fat percentage (combining males and females) were significant (2.60%, $p < .001$) although values were within the LSC of DXA-region (3.24%) and highly correlated ($r = 0.928$, $p < .001$). Further examination suggestions body composition in MS underestimated percent fat by 3.5% in males and 1.6% in females when compared to DXA-region. Previous comparisons between DXA and non-MS ultrasound have similarly found high correlations between body fat percentages in both sexes (25). In this study, MS tended to underestimate fat mass by 2.19 ± 2.46 kg while overestimating fat-free mass by 1.68 ± 2.55 kg, which parallels a recent report of fat mass underestimation by the device (2.2 ± 2.1 kg) (6).

The LSC calculated in this study was notably higher than that of Kaminsky et al. (16), who reported a LSC of 1.7% for DXA-region utilizing the Lunar Prodigy device. A similar device, the Lunar iDXA, is reported to have a much lower LSC of 0.7% for DXA-region body fat percentage (16). Several other studies have reported DXA LSC values for total, fat, and lean mass with various DXA devices but not body fat percentage (4, 8, 20, 21). LSC values are also commonly reported and evaluated on bone mineral density and its associated metrics (1, 2, 23).

Notably, this study utilized mid-prone hand positioning on DXA which may have an impact on body composition values. Previous studies comparing prone vs mid-prone hand placement have noted differences in regional bone mineral density, lean mass, and fat mass (19, 28). However, such regional differences are typically not great enough to significantly affect total body scores. Mid-prone positioning may have elevated fat mass, contributing to the mean differences in body fat percentages seen between DXA and MS. DXA produces two distinct fat percentages which allow interpretation as a two or three-compartment model: "Tissue %Fat" (three-compartment excluding bone from lean mass) and "Region %Fat" (two-compartment including bone within fat-free mass). This study utilized "Region %Fat" for proper comparison against the other two-compartment assessments.

Given the limitations of skinfold testing (29), technologies have emerged to examine body composition more precisely. Our study found that MS was reliable. Considering the affordability and portability of MS, practitioners may consider MS as a reliable option for measuring body composition which can be easily transported directly to clients. Furthermore, the low-dose radiation exposure of a DXA scan excludes some individuals including those who are pregnant or have certain medical implants. In contrast, MS may be a useful tool for body composition assessment in those who are excluded from DXA testing (17). The only known universal population limitation of MS is the inability to measure individuals with amputated limbs.

Some limitations to this study should be noted. Participants were asked to arrive fasted and rested but were not kept in a metabolic ward to ensure compliance. While the weight limit of DXA prevented the problem in this study, B-mode sonography has potential depth limitations for MS. MS may be unable to measure body composition values in individuals with greater subcutaneous adipose tissue thickness than 5cm (the maximal scanning depth utilized in this study), but the actual threshold is not yet determined. In addition, collecting MS images is a skill. Researchers completed two sessions of MS training and had previous ultrasonography experience but were not professional sonographers. A sonographer must undergo two or more years of coursework and instruction to complete a professional program. While accessible compared to other advanced body composition measurement technologies, MS requires training prior to utilization by a lay individual or sport coach looking for a better way to assess health and progress. However, the training required for MS is far less time-intensive than that for traditional ultrasonography. When properly trained on the device, non-clinical practitioners can utilize MS as an accessible way to reliably assess body composition.

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