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Validity of B-Mode Ultrasound for Body Composition Assessment in the Field

Original Research

Shane Draper[1], Conner Dearden[1], Nate Jensen[1], Brett Holmes[1], Andrew Creer[1]

[1]*Utah Valley University Human Performance Lab, Orem, UT*

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Abstract

Introduction: Identifying an accurate, user friendly alternative to skinfold calipers may allow for accurate assessment of body composition in more applied settings, such as various training and competition venues. The purpose of our study was to determine the validity of B-mode ultrasound (BMUS) for body composition assessment by comparing this method to values obtained using air displacement plethysmography (ADP).

Methods: Twenty-four active runners underwent two forms of body composition assessment during a single lab visit; ADP and BMUS. ADP body density was estimated using an air displacement chamber in combination with measured lung volume. BMUS body density was estimated from measuring the Jackson-Pollock 7 site skinfolds with a portable, app-based ultrasound device to determine subcutaneous fat thickness. Images were analyzed using proprietary software. Body density values for both methods were converted to body fat percentage using the Siri equation. A paired samples t-test was used to compare values obtained from ADP and BMUS.

Results: There was no difference between ADP (18.3 ± 7.3%) and BMUS (17.2 ± 7.6%; p = 0.1) for percent body fat.

Conclusions: BMUS provides a valid method for assessing body composition when compared to ADP, thus providing a portable, accurate method for assessing body composition in applied settings.

Key Words: Body Fat Percentage, Body Density, App-Based Ultrasound.

Corresponding author: Shane Draper, ShaneD@uvu.edu

Introduction

Ultrasound technology is commonly used in a clinical setting in order to study a person's abdominal and pelvic organs, heart, blood vessels, muscles, and tendons [1]. However, it can also be used to determine one's body composition. This is achieved by using ultrasound to provide a direct measurement of subcutaneous fat thickness. Body composition measurement provides a means for practitioners to monitor fat and lean body mass of individuals in response to weight fluctuations. In active populations, body composition measurements can be used to determine a healthy weight while also maximizing performance [2].

Body composition can be measured in a variety of ways, though each comes with its own limitations. Two valid laboratory-based methods of determining body composition are known as air displacement plethysmography (ADP) and Hydrodensitometry (HD)[3]. Air displacement plethysmography determines the volume of a subject by measuring the amount of air displaced by that individual in a chamber. This measurement can then determine body composition through the use of the equation models such as Siri or Brozek for white populations and Wagner and Heyward for non-white populations[4]. Hydrodensitometry involves the measurement of displaced water when a person's body is fully submerged. This is used to determine body volume from which body density and body fat percentage can be derived [3]. The Siri (percent body fat = [(4.95/body density) – 4.50] x 100)[5] and Brozek (percent body fat = [(4.57/body density) – 4.142] x 100)[6] equations are two component models that separate the human body into fat and fat-free components to obtain measures of body composition. These two equations were developed using the cadavers of white men and were based on three assumptions: 1) that the density of fat is 0.9007 g/cm^3, 2) that the density of the fat free mass is 1.100 g/cm^3, and 3) that the proportions and densities of the fat free mass components (water = 73.8%, 0.9937 g/cm^3; protein = 19.4%, 1.34 g/cm^3; and mineral = 6.8%, 3.038 g/cm^3) are constant for all individuals[4,6]. However, the fat free mass of blacks is greater (1.1057 g/cm^3)[4] than what is assumed for whites thus the Siri and Brozek equations will underestimate body fat percentage in black men by 3%[6]. As a result, Wagner and Heyward developed an equation (percent body fat = [(4.858/body density) − 4.394] × 100)[4] based on the fat free body density of black men. There is also a similar race-specific equation reported by Ortiz et al. to estimate body fat percentage in black women[7]. Unfortunately, there are situations when lab-based measures are inconvenient, expensive and/or impractical. The most common field-based method to assess body composition is to measure skinfold thickness as an indirect estimate of subcutaneous fat. Typically, skinfold thickness is measured at three to seven specific sites on the right side of the body, and the sum of the skinfolds is inserted into an equation to predict body density, which is then converted to body composition[8]. Though this process provides the convenience of an in-field measurement, it can also be highly variable depending on practitioner experience.

Ultrasound can be used as a less invasive, more cost-effective, and practical alternative to obtaining body composition measurements. The two most common ultrasound devices used in body composition research are amplitude mode (A-mode) and brightness mode (B-mode). B-mode ultrasound displays a 2D image of tissue, while A-mode displays a graph with peaks and waveforms indicating an interface of two different tissues. Low (A-mode) and high resolution (B-mode) ultrasound has been validated by comparing fat thickness at various sites to actual fat measurement in cadavers [8]. Both types of ultrasound produced fat thickness measurements within a millimeter of the actual measured fat thickness, suggesting that both types of ultrasound provide an accurate assessment of subcutaneous fat thickness [9].

To date, only a few studies have been performed involving the use of A-mode ultrasound to determine body composition in college-age athletes[10–12]. However, the validity of B-mode ultrasound remains less clear. The purpose of this investigation was to compare body composition values determined by B-mode ultrasound to those obtained by ADP in an active, adult population. We hypothesized that B-mode ultrasound would be a valid and practical method to measure subcutaneous fat in this population and that those results could be used to find an accurate body fat percentage.

Scientific Methods

Participants

Twenty-four active runners, long-distance runners (active runners defined as ≥ 4 hours/ week for the last year) participated in this study. Participants (36.8 ± 10.7 yrs; 173.1 ± 9.9 cm; 69.6 ± 12.4 kg) include males (n=14) and females (n=10) that randomly underwent two forms of body composition assessment using a counterbalanced design. All participants underwent both ADP and BMUS methods of body composition measurement within a 30-minute period on the same day. This study was approved by the Utah Valley University Institutional Review Board (IRB log number 729). All participants read and signed the approved informed consent form after being instructed about the purpose of the study.

Protocol

During a single lab visit, participant's body composition was randomly assessed by means of ADP and B-mode ultrasound (BMUS). Participants arrived at the laboratory in a fasted state (>2 hours) having refrained from all exercise in a 24-hour period prior to testing. Throughout the study a trained technician retrieved BMUS and ADP measurements. The technician was blinded to the results until after the completion of both tests. This was done in order to prevent any manipulation or bias.

B-Mode Ultrasound Scans

This procedure involved the non-invasive scanning of the Jackson-Pollock 7 site skinfold locations (chest, sub-scapular, triceps, mid-axillary, supra-iliac, abdominal, and thigh) with a portable, app-based ultrasound device (Philips

Lumify) to determine subcutaneous fat thickness (SFT) [8]. The sum of the skinfold sites were used to determine body density and body composition was predicted using the Siri equation. The clearest image for each site was then uploaded and analyzed using proprietary software (MuscleSound, Glendale, CO) to determine body composition. To improve image quality, the ultrasound probe was coated with conductive gel prior to each site measurement. The ultrasound technician was responsible for applying the gel to the ultrasound probe. The technician was trained by MuscleSound and was instructed to apply the thinnest layer of gel possible that provided a clear image and uninterrupted probe skin contact. If too much gel was used a solid dark feature was visible across the top image before the start of the dermis. If this occurred, the technician removed the excess gel or spread the gel thin by swirling the probe in circular motions until the image cleared and the probe had interrupted skin contact.

Air Displacement Plethsmyography

The ADP measurements were obtained using the Bod Pod (COSMED, USA). Each participant was required to wear tight-fitting clothing (lycra swimsuit or compression clothing), as well as a lycra swim cap to reduce air volume inconsistencies. Before entering the Bod Pod, each participant was measured in height (cm/in) and weight (kg/lbs). Next, they were asked to passively sit inside the enclosed Bod Pod air chamber for 2-3, 40-second intervals, during which time the chamber was filled with an imperceptible amount of air in order to determine body volume, from which body density and ultimately body composition were calculated. The chamber was opened between each 40 second interval to reset air volume. After the initial 40 second interval, a breathing tube was used in subsequent intervals in order to measure thoracic gas volume. This procedure was done per the standardized and published COSMED protocol which has been previously described in detail[13–15]. Body density values for both the ADP and BMUS methods were converted to percent body fat utilizing the Siri equation.

Statistical Analysis

A paired t-test was used to compare values obtained from each method ($p < 0.05$). To assess the test-retest reliability of the technician, a Pearson Correlation coefficient (r) and 95% confidence intervals (CI) were calculated comparing the ADP and BMUS measurements. Effect sizes were considered as small (0.10), medium (0.30) and large (0.50) based on the Cohen method of classification. R^2 was calculated from the regression equation of the ADP % Body Fat prediction of the BMUS % Body Fat from Figure 1. A Bland-Altman plot was also used to depict residual scores.

Results

The intra-rater reliability was strong as indicated by the Pearson Correlation (0.976) and 95% CI of 0.90 - 0.995. No significant difference was found between ADP (18.3 ± 7.3%) and BMUS (17.2 ± 7.6%) for percent body fat ($p = 0.1$). In addition, data analysis revealed a strong, positive correlation ($R^2 = 0.84$) for values obtained from ADP and BMUS methods (Figure 1). The mean difference between ADP and BMUS values was -1.2 ± 3.1%. A Bland-Altman plot was used to determine the upper and lower 95% limit of agreement between ADP and BMUS (Figure 2).

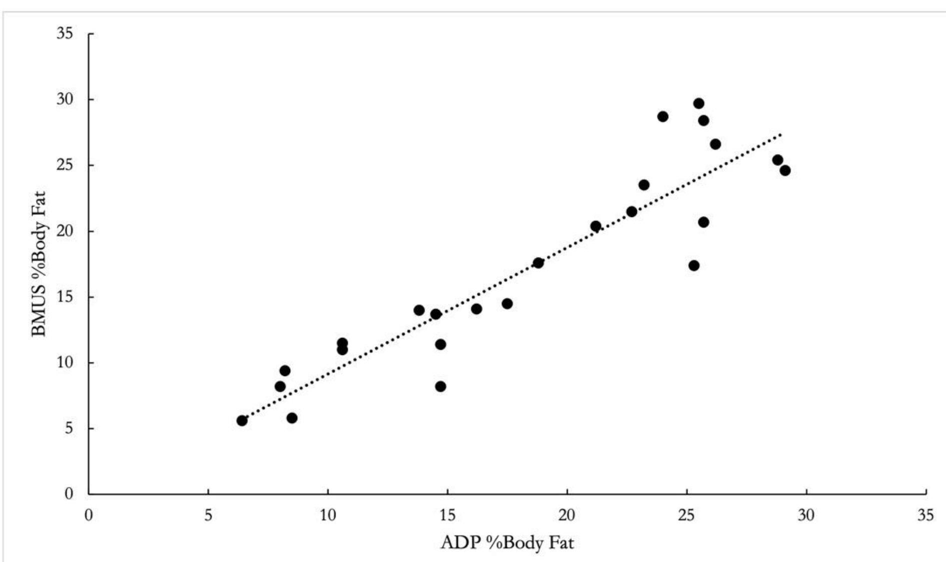

Figure 1. A comparison of percent body fat values determined from ADP and BMUS ($R^2 = 0.84$).

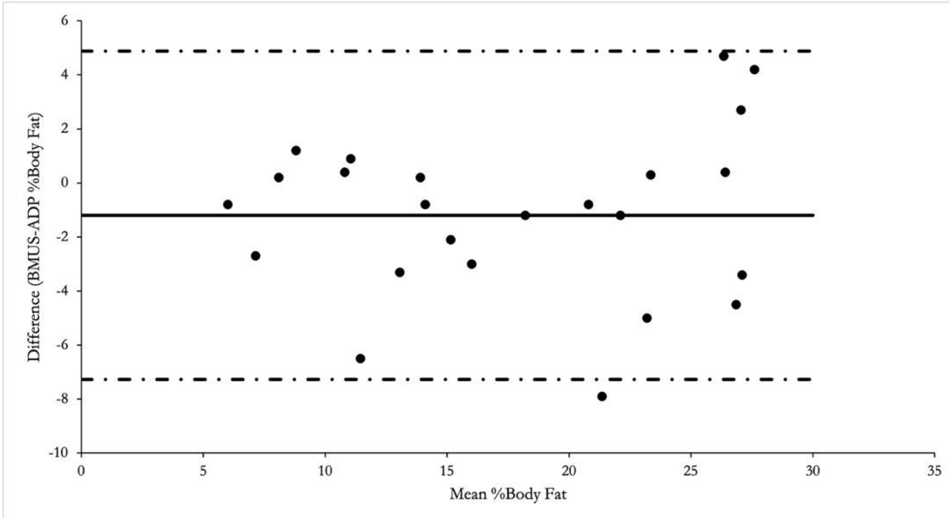

Figure 2. Bland-Altman plot measuring the difference between ADP and BMUS body composition values. Y-axis values represent the difference between BMUS and ADP values. The X-axis represents the mean of the BMUS and ADP values. Dashed lines represent the lower (-7.276) and upper (4.876) bounds of the 95% limit of agreement interval, while the solid line represents the mean difference (-1.2) between ADP and BMUS values.

Discussion

The main findings from this investigation suggest a strong, positive correlation between %BF results from ADP and BMUS in active adults. It appears, however, that there is a potential decrease in agreement in individuals with > 23% BF (Figure 2). Our study advances the findings of Wagner and colleagues [6] in which they compared the body composition measurements of A-mode ultrasound (AMUS) to BMUS in human cadavers. In one of the female cadavers, the greatest divergence among measurements occurred. This female cadaver also had the largest subcutaneous fat thickness. Due to the small sample size Wagner et al., could not determine if a larger fat thickness resulted in the measurement errors of if it was simply happenstance. They also found that the AMUS measurements were relatively similar at each site and suggested that there is greater difficulty interpreting BMUS images as subcutaneous fat thickness (SFT) increases [9]. Our study also supports findings observed from Müller et al.,[16] who found that when using US to measure SFT, the abdomen measurement accounted for the majority of images that could not be accurately measured. This was suggested due to the abdomen being one of the sites which typically contains a larger SFT.

In contrast to our study, other studies claim that properly identifying SFT by means of BMUS in very lean athletes can be increasingly difficult [17–19]. Chandler et al., suggest this can be due to sites where more fascia is present such as the suprailiac and subscapular locations [18]. It has also been observed that US can act as an effective mode of body fat percentage (BF%) measurement in obese individuals [20,21]. Our findings directly challenge this sentiment as greater agreement between ADP and BMUS occurred in leaner participants than in those with a greater BF%.

We chose to compare the results from BMUS to ADP as ADP has proven to be a valid lab-based method of obtaining BF%. Hydrodensitometry and ADP are densitometric methods that rely on measurements of one's mass and volume to calculate body density (D_b). Hydrodensitometry has long been an accurate method of obtaining D_b. However, ADP serves as a more convenient lab-based method as it requires less technician expertise, is more time efficient, and comfortable due to air being used as the displacement medium rather than water. A review found that among 12 studies comparing ADP to HD, the average of the study means agreed within 1% BF [22]. Several other studies show evidence concerning validity of measuring D_b in ADP when compared with HD [13,14,23–25].

Though ADP has proven to be a convenient and valid lab-based method, US provides a great, low cost or field-based alternative to body composition measurement. For example, ADP can be very costly, therefore, more convenient and cost-effective options such as the skinfold measurement have been used. However, skinfold can remain problematic and less reliable than US [12]. Wagner et al., found that the AMUS technique proved to have a much higher inter-rater reliability than the skinfold, making it more likely for multiple examiners to obtain similar results [12]. Though our study focused on BMUS, an excellent reliability score was also observed with our intra-rater test-retest reliability results.

Our study was in congruence with several others that have noted US as a promising method to assess BF %. However, the key difference involves these studies recording measurements by means of AMUS or having analyzed results on young active populations [11,12,18]. For example, Chandler et al., found BMUS as a reliable form of BF% measurement, but, the study was conducted on a young healthy population of ballet dancers (Male $M_{age} = 17.2 \pm 1.7$ yr; Female $M_{age} = 16.1 \pm 1.4$ yr) [18]. Additionally, Pineau et al., found US BF% measurements were closely correlated to estimates with those of DEXA, but, this study was conducted using AMUS in place of BMUS [11]. We focused on a method of measurement and participant group where little to no research has been conducted. The published BMUS research, to date, has focused on young vocational ballet dancers [18] and cadavers [9]. The published AMUS research has mainly focused on collegiate athletes [11,12,26] and in a non-trained adults (21.9 - 41.8 years) [27]. In our lab, wanted to focus on a healthy adult population for future research in areas such as endurance events where body composition changes can be evaluated during the course of a 24 hour to 1 week period of activity in which body weight changes in an individual participant are likely. Most of the participants in these activities are in their 30s and 40s.

Body composition provides critical information such as %BF that can be utilized by researchers or practitioners to monitor fat free mass in conjunction with changes in weight. While ADP provides accurate values for body composition, it is not a feasible option for field work as it is a method confined to the laboratory. Current efforts to measure body composition in settings outside of the lab include the skinfold assessment which uses special calipers to estimate subcutaneous fat thickness at various sites. As can likely be deduced, the use of calipers in accurately measuring subcutaneous fat thickness at the precise locations can be a potential source of error based on the experience and knowledge of the practitioner. The current data suggest that BMUS may offer a comparatively accurate alternative to other lab and field-based methods.

Potential limitations in measuring BF% with BMUS in certain participants could be due to technician error at higher BF% values. The technician is expected to determine the correct SFT by analyzing the BMUS images obtained. Due to the larger SFT in certain participants, it can become increasingly difficult to determine the precise thickness.

Additionally, in individuals with a higher BF%, it can be difficult for the technician to use the correct amount of pressure on the BMUS probe. Slight pressure is required to obtain a clear BMUS image. However, too much pressure can result in the decompression of the subcutaneous fat layer which causes an underestimation of BF%. Too little pressure on the probe can result in poor image quality and an overestimation of BF%. This could have potentially caused the decrease in agreement between the BMUS and ADP results in the participants on the larger end of the BF% range.

Conclusions

B-mode ultrasound values demonstrated a high, positive correlation with ADP body composition values; however, the Band-Altman plot revealed a potential decrease in agreement at the higher end of the measured body fat range. Overall, it appears that BMUS appears to be a valid method for assessing body composition in lean, active males and females when compared to ADP, making it a suitable, portable option for body composition assessment in the field.

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