Use of B-Mode Ultrasound as a Body Fat Estimate in Collegiate Football Players

Parker N. Hyde,[1] Kristina L. Kendall,[2] Ciaran M. Fairman,[1] Nicholas A. Coker,[3] Mary E. Yarbrough,[3] and Steve J. Rossi[3]

[1]Department of Health and Kinesiology, College of Education and Human Ecology, Ohio State University, Columbus, Ohio; [2]Bodybuilding.com, Boise, Idaho; [3]Human Performance Laboratory, School of Health and Kinesiology, Georgia Southern University, Statesboro, Georgia

Abstract

Hyde, PN, Kendall, KL, Fairman, CM, Coker, NA, Yarbrough, ME, and Rossi, SJ. Utilization of B-mode ultrasound as a body fat estimate in collegiate football players. *J Strength Cond Res* 30 (12): 3525–3530, 2016—The purpose of the present study was to validate a 7-site ultrasound imaging protocol to predict the percent body fat (%BF) in a division I football team. Body composition was estimated by ultrasound, 7-site skinfolds, and the 3-compartment-water (3C-W) model of Siri, using bioimpedance spectroscopy to estimate the total body water and air displacement plethysmography (using BODPOD) to determine the body density. Pearson's product-moment correlation analyses were run to determine correlations between $\Sigma_{Ultrasound}$ and the criterion 3C-W, and between the $\Sigma_{Skinfold}$ and $\Sigma_{Ultrasound}$. Strong positive correlations were observed between $\Sigma_{Skinfold}$ and $\Sigma_{Ultrasound}$ ($r = 0.984$; $p < 0.001$). Furthermore, a strong positive correlation was observed between $\Sigma_{Ultrasound}$ and %BF from 3C-W ($r = 0.878$; $p < 0.001$). Based on the significant correlation analysis, a linear regression equation was developed to predict the %BF from $\Sigma_{Ultrasound,}$ using %BF from the 3C-W model as the dependent variable: %BF = $6.194 + (0.096 \times \Sigma_{Ultrasound})$; standard error of the estimate (*SEE*) = 2.97%. Cross-validation analyses were performed using an independent sample of 29 players. The mean observed %BF from the 3C-W model and the mean predicted %BF were 18.32 ± 6.26% and 18.78 ± 6.22%, respectively. The constant error, *SEE*, and validity coefficient (*r*) were 0.87%, 2.64%, and 0.91%, respectively. The total error was 2.87%. The positive relationship between ultrasound measurements and the 3C-W model suggests that ultrasound imaging may be a practical alternative to predicting % BF in division I football players.

Key Words 3-compartment model, validation, athlete, skinfold

Address correspondence to Parker N. Hyde, hyde.110@osu.edu.

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Introduction

Body composition has been proposed to be a significant predictor of performance in several tests for football athletes, including vertical jump and sprint performance (10). Moreover, the ability of an individual to produce an isometric force is directly related to the muscle mass of that individual (21). Previous research suggests that an increased body mass (BM) as a result of an increased fat-free mass (FFM) has led to increases in the performance of division I football players (13). Contrastingly, an increase in the fat mass relative to the FFM can result in performance decrements demonstrated by decreases in both speed and power, as well as an increased risk of cardiovascular disease, stroke, and all-cause mortality (7,10,13). Thus, the achievement and maintenance of an ideal body composition is important to the success and health of football athletes.

The estimation of body composition is a highly used practice by athletes and coaches alike (11). Body composition can be assessed using different laboratory and field measures. Dual energy x-ray absorptiometry (DEXA) uses a low dose x-ray radiation to determine the percent body fat (%BF) and bone mineral density of the individual being tested. Although DEXA has been shown to be a valid measurement of body fat, the cost of purchase makes it impractical for the majority of athletes and coaches (16). Additionally, it can be difficult for larger athletes to fit within the measurement parameters of the DEXA bed. Hydrostatic weighing (HW), which has long been considered the "gold standard" for body composition testing can also have its drawbacks, specifically the time required for testing. This mode of testing may not be feasible when testing large groups of individuals, like an American football team, because of the length of time needed to test everyone. Consequently, the cost of equipment, potential size limitations, and time requirements for these tests make them inefficient for a large team such as the American football team.

Field measures for the assessment of body composition are generally portable and more affordable. The use of field tests also allow for a more convenient method of repeated measurements of body composition over the course of an athletic season. Skinfold measurement is a commonly used method of assessment. When measured by a trained technician, skinfold thickness and the resulting estimation of body fat have a high degree of agreement with the associated multicompartment criterion method (3). However, the use of skinfold measurements are more difficult in overweight and obese subjects. This is primarily due to the thicker adipose tissue making the proper isolation of a fold more difficult (5). Skinfold measurements are also limited by access to trained assessors, high interrater error, and an inability to palpate the adipose and muscular fascia border (22).

Bioelectrical impedance spectroscopy (BIS), another field-based tool, operates through the assessment of impedance from a small electrical current sent through 2 electrodes. Although a relatively quick method, body fat estimations from BIS can be highly variable and have been called into question as an accurate assessment in collegiate football players (14).

Ultrasound (US) has been proposed as an alternative noninvasive technique to measure subcutaneous fat thickness. Ultrasound imaging principally works by sending an acoustic wave from a transducer and interpreting the reflection of the wave by a receiver, which is located within the transducer. These reflections are interpreted by the machine and displayed as a 2-dimensional image (23). The use of a brightness mode (B-mode) US as a measure of body composition has been found to be a valid and reliable way to estimate the body fat of an individual (15,23). Although there is a lack of cohesive standards for imaging sites, and estimation of body composition using US, the ease of distinguishability of tissue planes, and the ability to measure depth without pinching the skin using on-screen calipers offer a considerable advantage of skinfold measurements.

To our knowledge, no studies have investigated the validity of a B-mode US to estimate the %BF in collegiate football players. Therefore, the purpose of this study was to examine the relationship between US, skinfold measurements, and a criterion 3-compartment-water (3C-W) model, and to develop a regression equation to predict %BF from US measurements in collegiate football players.

Methods

Experimental Approach to the Problem

A cross-sectional experimental design was applied to assess the body composition of American football players in a division I collegiate team. A singular testing session included all the body composition measurements in the order BODPOD, BIS, skinfold, and US. Bioelectrical impedance spectroscopy, skinfold, and US were each performed by the same technician to eliminate interrater variability. The relationships between %BF from skinfold and %BF from US, as well as the $\Sigma_{\text{Ultrasound}}$ and %BF 3C-W were assessed. A regression equation was then generated to predict the %BF using $\Sigma_{\text{Ultrasound}}$.

Subjects

Fifty-eight collegiate division I football players, including both African Americans ($n = 48$ [age, 20.33 ± 1.24 years; weight, 96.61 ± 19.14 kg; height, 179.71 ± 6.26 cm]) and Caucasians ($n = 10$ [age, 20.10 ± 1.29 years; weight, 100.76 ± 18.23 kg; height, 182.63 ± 5.47 cm]) volunteered to participate in this study approved by the Georgia Southern University Institutional Review Board (Protocol#: H15032). All participants provided written informed consent before participation. Participants were asked to arrive to the laboratory hydrated, in a fasted state (minimum of 8 hours), and to abstain from exercise 24 hours before testing. Water intake was allowed 1 hour before testing. The study required players to provide informed consent before participation.

Procedures

Total Body Water. Bioelectrical impedance spectroscopy (BIS) was used to estimate the total body water (TBW) following the procedures recommended by the manufacturer (Bodystat Quadscan 4000; Bodystat Ltd., Douglas, United Kingdom). After resting in a supine position for 10 minutes, TBW estimates were taken while the participants lay on a table with arms ≥30° away from the torso and legs separated. Before each analysis, each participant's height, weight, and gender were entered into the BIS device. The electrodes were placed at the wrist (dorsal surface at the ulnar styloid process) and ankle (dorsal surface between the malleoli) with additional electrodes being placed 5 cm distally from the wrist and ankle. Before electrode placement, excess body hair was removed, and the skin was cleaned with alcohol at each site. Multifrequency (5, 50, 100, and 200 kHz) currents were introduced from the positive leads and traveled throughout the body to the negative leads. Resistance values were used to calculate the extracellular water and intracellular water and summed to equal TBW.

Air Displacement Plethysmography (BODPOD). Body density (Db) was estimated from air displacement plethysmography using the BODPOD (COSMED, Rome, Italy). Before each test, the BODPOD was calibrated according to the manufacturer's instructions using a 2-point calibration. It was first calibrated with the chamber empty, and then with a cylinder of known volume (50.097 L). Before testing participants were instructed to wear tight-fitting compression shorts and a swimming cap, and were asked to remove all metal, including jewelry and watches. Body mass was measured to the nearest 0.01 kg using the system's calibrated scale. Participants were instructed to sit in the chamber, breathe normally, but minimize any movement. A minimum of 2 trials

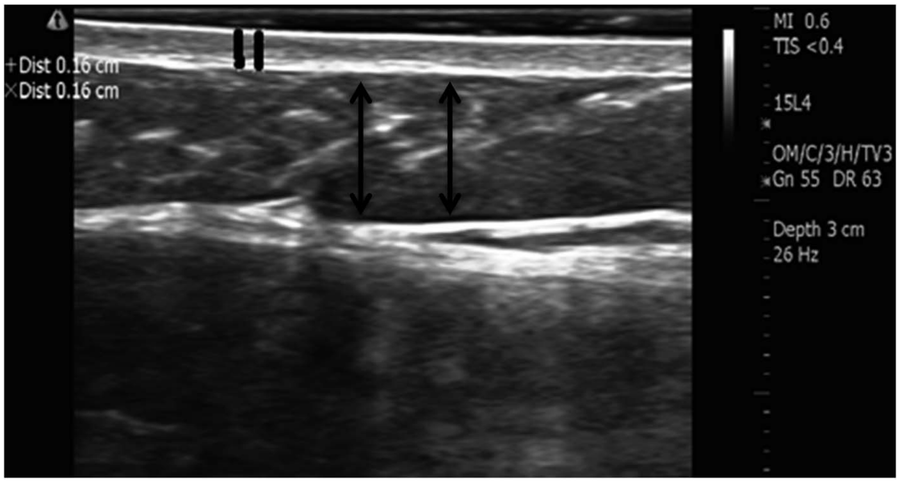

Figure 1. Measurement of subcutaneous adipose tissue.

were performed, and if measurements were not within 150 mL of each other, a third trial was conducted. Thoracic gas volume was estimated using the BODPOD software, which uses standard prediction equations.

The 3C-W Model. The criterion %BF was estimated using the 3C-W model described by Siri (19). The equation includes measurements of the Db (from the BODPOD), TBW (from the BIS), and BM. The equation for %BF is listed below:

$$\%BF = [(2.118/\text{Body density}) - (0.78 \times \text{TBW(L)}/\text{BM(kg)}) - 1.354] \times 100$$

Skinfolds. Skinfold measurements were taken on the right side of the body with a calibrated Lange caliper at the following sites: chest, triceps, subscapular, midaxillary, abdomen, suprailium, and thigh. Skinfold measurements were made in duplicate at each site and recorded to the nearest 0.5 mm, with a third measurement taken if the values differed by more than 2 mm. All skinfold measurements were performed by a trained technician. Body density values were calculated using the generalized skinfold equation of Jackson et al. (6). Percent body fat was calculated from Db using the formulas of Brozek and Wagner and Heyward (2,24).

Ultrasound. Ultrasound measurements were taken using a T3200 ultrasound imaging device (Terason, Burlington, MA, USA), with a resolution of 26 MHz, to measure subcutaneous fat thickness. All measurements were taken on the right side of the body while the participant was standing using the 7-site skinfold locations according to

Table 1. Descriptive characteristics of development and cross-validation groups (mean ± *SD*).

Variable	Development group (*n* = 29)	Cross-validation group (*n* = 29)	Combined (*n* = 58)
Age (yrs)	20.24 ± 1.3	20.3 ± 1.2	20.3 ± 1.2
Height (cm)	179.0 ± 7.07	181.4 ± 5.0	180.2 ± 6.2
Weight (kg)	96.1 ± 19.62	98.6 ± 18.4	97.3 ± 18.9

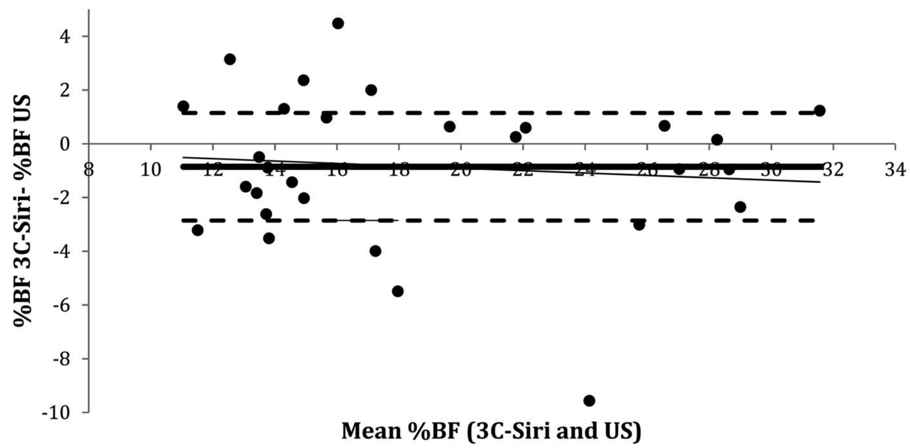

Figure 2. Bland–Altman plot of the difference between the percent body fat (%BF) measured by the 3-compartment-water (3C-W) model and the ultrasound (US). The light solid line indicates the line of best fit, the heavy solid line indicates the mean difference, and the dotted lines (mean difference ± 2 *SD*) indicate the upper and lower 95% limits of agreement.

Jackson et al. (6). The Jackson and Pollock skinfold locations were used, instead of the International Society of Advancement of Kinanthrometry (ISAK) sites, owing to the common usage of sites and the American College of Sports Medicine general anthropometry recommendations. Measurements were taken by applying transmission gel to the transducer and lightly placing the transducer parallel to the site. Care was taken to control the pressure of the transducer with minimal movement across the skin. The transducer was positioned so that a clear image was viewable on the monitor of the US. Once a clear image appeared, it was saved and labeled, and researchers progressed to the next site. At a later time point, the researchers returned to the saved images to measure the thickness of the subcutaneous fat layer (Figure 1). Researchers clearly distinguished fascial planes and then calculated subcutaneous fat thickness, to the nearest 0.01 cm, using the electronic calipers associated with the T3200 software. Two measurements were taken for each site, with the average used for the final measurement. All 7 values were summed ($\sum_{\text{ultrasound}}$).

Statistical Analyses

Twenty-nine football players were randomly selected from the pool of 58 for the derivation of the prediction equation.

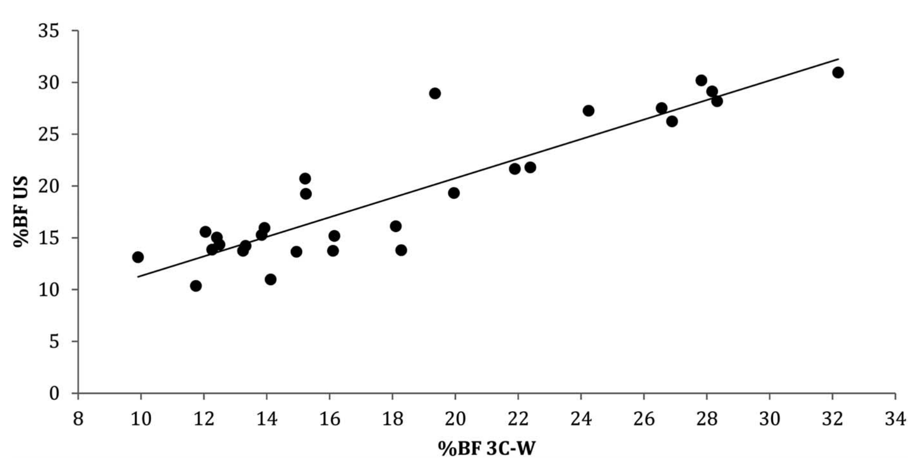

Figure 3. Comparison of the percent body fat (%BF) determined by the 3-compartment-water (3C-W) model and the ultrasound (US) in collegiate football players. Validity coefficient = 0.91, standard error of the estimate (*SEE*) = 2.64%.

Means for the groups can be found in Table 1. Pearson's product-moment correlation analyses were run to determine the strength of the relationship between $\Sigma_{Ultrasound}$ and $\Sigma_{Skinfold}$, and the strength of relationship between $\Sigma_{Ultrasound}$ and the criterion %BF from 3C-W. A linear regression was used to generate a prediction equation for determining %BF using $\Sigma_{Ultrasound}$ using 3C-W as the criterion method.

Cross-validation analysis of the new equation was conducted on the sample of 29 football players who were withheld from the derivation of the equation. Constant error (CE), total error (TE), correlation coefficient (*r*), and standard error of the estimate (*SEE*) were calculated. Correlation coefficients and bias ±95% limits of agreement (as represented by the Bland–Altman plot (1); Figure 3) were used to assess the relationships between the criterion %BF using the 3C-W model and the predicted %BF using the US. SPSS (version 21; IBM, New York, USA) was used for all statistical comparisons. The α-level was set at $p \leq 0.05$ to determine statistical significance. All data are reported as mean ± *SD*.

Results

A significant, positive relationship was observed between %BF from skinfold and %BF from US (Wagner and Heyward: $r = 0.976$; $p \leq 0.05$; Brozek: $r = 0.984$; $p < 0.001$). A statistically significant and positive correlation was observed between $\Sigma_{Ultrasound}$ and %BF from 3C-W ($r = 0.878$; $p < 0.001$). Based on the significant correlation analysis, $\Sigma_{Ultrasound}$ was entered into a regression equation. The following equation was developed to predict %BF from $\Sigma_{Ultrasound}$:

$$\%BF = 0.096(\Sigma_{ultrasound}) + 6.194; SEE = 2.97\%$$

Cross-validation analyses using the sample of 29 football players withheld from the derivation of the equation, resulted in a mean predicted %BF of 18.78% compared with the criterion %BF of 17.91% (Figure 2). The CE value of 0.87% was not significant ($p > 0.05$). The *SEE* and validity coefficient (*r*) were 2.64% and 0.91, respectively. The TE value was 2.87%.

Discussion

The primary purpose of this study was to evaluate the use of an US imaging technique via 7-site measurement as a predictor of %BF in collegiate football players. Our results indicate a significant positive correlation between %BF determined from skinfold and US, and are in agreement with the findings of Fanelli and Kuczmarki (4), who found that US produces %BF estimates similar to skinfold calipers in a nonathletic, Caucasian population.

This is in contrast to previous research which found that US was not a valid measure when compared with skinfold or 3C-W measurements (8,20). Two primary reasons may explain this apparent discrepancy. Primarily, the Loenekke and Smith-Ryan studies employed an A-mode US. The A-mode US uses a much lower frequency (2.5 MHz) and therefore has less penetrating depth for measurements. A secondary rationale for the differences in findings is the difference in number of sites used for US measurement. Loenneke et al. (8) obtained 1-site and 3-site measurements, whereas the current study used a 7-site measurement. The addition of greater number of sites in the present study may have provided a more accurate representation of total body fat. Although US and skinfold have been shown to have a high level of agreement, skinfold measurements can overestimate the %BF in individuals with higher levels of subcutaneous fat (17). Furthermore, although skinfold measurements may be acceptable for tracking changes over time, higher degrees of interrater error reduce the likelihood that measures will be consistent when using skinfold unless the same person performs the measurements each time (22).

The secondary purpose of this study was to develop a prediction equation that may be used to accurately predict the %BF in collegiate football players using US. The *SEE* from the produced regression equation was 2.97%, which indicates that the equation may be accurately used for prediction of the %BF in this population. The findings of the present study are in agreement with those of Müller et al. (12), which found that US, following the 10-site ISAK standard, was an accurate estimator of the %BF in a healthy population.

In agreement with the current study, Fanelli and Kuczmarki (4) demonstrated a nonsignificant difference between the criterion (HW) results and results of a predictive regression equation using US measurements, whereas the present study demonstrated a nonsignificant difference between the criterion (3C-W) and the generated prediction equation. In contrast, Smith-Ryan et al. (20) found that US tended to underestimate the %BF in overweight and obese men and women when compared with the 3C-W model. However, their study used A-mode US (using amplitude as opposed to brightness), which could potentially produce erroneous results in an overweight population because of changes in the pulse through the thicker adipose tissue (20).

Evaluation of the results of the cross-validation analysis were established according to previous research completed by both Sinning et al. (18) and Malek et al. (9), including the following criteria: (a) the mean values for observed and predicted %BF should be comparable; (b) the TE should be calculated because it reflects the true difference between the actual and predicted values for %BF, whereas the *SEE* only gives an indication about the error associated with the regression between the variables; (c) the TE and *SEE* should be similar because this reflects the relationship between the regression line for actual vs. predicted %BF and the line of identity; (d) a low *SEE* is preferred over correlation coefficients owing to the *SEE* not being sensitive to differences in means and being affected by the differences between samples in variability of %BF; and (e) there should be no relationship between the CE and %BF (18). The *SEE* from the cross-validation analysis of the current study was 2.64%, indicating minimal difference between the observed %BF values and those predicted from the regression equation. The TE was 2.87%, which indicates a strong relationship between the observed and predicted values. The closeness of these values to each other and the nonsignificant CE value of 0.87% indicate that the associated regression equation is a valid measure for estimating the %BF in collegiate football players. Taken together, these results support the use of the developed equation to predict %BF in American football players.

Future research should aim to validate the developed equation in other populations such as high-school football players and other collegiate athletes. Additionally, the researchers are in agreement with Müller et al.(12) that there is a need to develop and validate standardized techniques for the assessment of body composition using US to ensure uniform assessments and estimations of %BF from this method.

Practical Applications

The results of this study indicate that a 7-site US technique, as a measure of %BF, may produce results similar to skinfolds making it a cost-effective, time-efficient alternative to typical laboratory testing methods for coaches. Ultrasound offers other distinct advantages over skinfold measurements. The high degree of interrater error seen when using skinfold measurements may be reduced when using US imaging because of the ability to capture and save images (22). Additionally, because US does not require isolation of folds, it may be easier to measure the full thickness of adipose tissue.

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