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Comparison of the Three-Site and Seven-Site Measurements in Female Collegiate Athletes Using BodyMetrix™

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ABSTRACT

International Journal of Exercise Science 14(4): 230-238, 2021. One method to measure body composition that is gaining popularity is the BodyMetrix™, which uses A-mode ultrasound. A-mode ultrasound, when used with the BodyMetrix™, has been found to be a reliable and a cost-effective tool for measuring overall body fat percentage. Furthermore, the portability and short duration testing features of the BodyMetrix™, allows for testing of a large group of athletes inside or outside of a clinical setting. Despite these advantages, research regarding the BodyMetrix™ is limited and has primarily focused on the seven-site testing technique. However, the three-site technique allows for faster testing and a reduction of time needed to test an entire team or multiple sports teams. Thus, the purpose of this study was to compare the three-site and seven-site methods using the BodyMetrix™ to determine body fat percentage in female collegiate athletes. It was hypothesized that body fat percentage determined via the seven-site method would be different from those obtained by three-site measurement technique. Study participants included 40 National Collegiate Athletic Association (NCAA) Division-II female athletes from volleyball, soccer, and softball teams. The Jackson Pollock three-site (thigh, suprailiac, triceps) and seven-site (thigh, suprailiac, triceps, abdominal, subscapular, chest, and axilla) equations were used to determine body fat percentage values. The time required to perform the three-site and seven-site measurements were also recorded. A paired samples *t*-test was used to assess if there was a difference between the three-site and the seven-site body fat percentage measurements with the use of the BodyMetrix™ . The three-site method (23.21 ± 3.61) was significantly lower ($p < 0.001$) compared to the seven- site method (25.75 ± 4.39). On average, the three-site technique took 2 minutes and 13 seconds less than the seven-site technique.

KEY WORDS: A-mode ultrasound, body composition, female athlete, Jackson Pollock equation

INTRODUCTION

Body composition is a method of determining the ratio of the body's fat mass (FM) and fat free mass (FFM) (8). The measurement of body composition can be used in both general and athletic populations for bringing awareness to a person's overall health-related and fitness-related components of life, as well as reducing overall mortality rates (8, 18); therefore, this information can be vital to overall health. However, athletes can also benefit from a lower body fat percentage. This is especially true in sports where a high body mass can have a significant effect on performance (16, 18). For example, sports such as wrestling require weight classes, so having low body fat percentage (BF%) can be advantageous to performance.

Tracking of body composition is critical for many athletes. Athletes are not only striving to increase their level of performance but are also trying to improve body composition as a method to help achieve their maximal performance levels. In addition to providing advantages for weight-division based sports, measurements of body composition are useful for tracking changes throughout the duration of a sports year (preseason, regular season, and postseason).

Currently, there are many different methods used to determine body composition (18, 19). The simplest approach for determining body composition is the two-component model, which separates body mass into FM and FFM (5, 8). Common body composition measurement tools include skinfold calipers, air displacement plethysmography, bioelectrical impedance analysis, hydrodensitometry, underwater weighing, and A-mode ultrasound (8). The current gold standard for measuring body composition is using Dual-energy X-ray absorptiometry (DEXA), which is a reliable measure that can divide the body into three components: bone, fat-free and bone-free tissue, and fat (6). Despite the benefits of DEXA, it, like other laboratory methods, is not commonly available in all locations due to the size and cost of the equipment (18, 19). Compared to DEXA, skinfold calipers are an inexpensive, portable, and more efficient method for determining body composition, and thus, more commonly used (13, 18). Because of the skill and consistency needed while pinching during skinfold measurements, interrater reproducibility is not high when measuring for percent body fat. This inconsistency can lead to doubts about the accuracy of the skinfold technique (13).

Due to the inaccuracies with various body composition measurements, A-mode ultrasound, a newer method of measuring body composition, has been looked at, and it has been shown to be both valid and less invasive compared to DEXA (1). A-mode ultrasound transmits an ultrasound beam through the skin, the beam is reflected back to the transducer as an echo when it contacts subcutaneous fat, muscle, and bone (1). BodyMetrix™ utilizes A-mode ultrasound, or the amplitude mode ultrasound technique. Amplitude mode is when the transducer utilizes a narrow beam to scan tissue discontinuity (16). B-mode ultrasound or brightness modulation, scans using a linear array to produce a two-dimensional image. B-mode ultrasound then involves using electronic calipers to measure subcutaneous fat layer thickness on the two-dimensional images (16). Thus, the utilization of A-mode ultrasound by BodyMetrix™ makes it an alternative measurement method for accurately measuring body composition.

Compared to measuring body composition with DEXA, the novel and user-friendly BodyMetrix™ offers a portable field test method. Unlike DEXA, the BodyMetrix™ does not utilize or expose the participant to low dose radiation to determine body composition. The BodyMetrix™ seven-site method has been proven to be as accurate as the DEXA when estimating the percent of adipose tissue (1). However, the BodyMetrix™ is more cost effective compared to DEXA, which allows the A-mode ultrasound to have increased utilization in different populations and settings. The BodyMetrix™ is a more cost-effective body composition tool than the DEXA because of the BodyMetrix™ 's cheaper purchase price and lack of special training needed to operate the equipment. The benefits of the ultrasound as a method used to determine body composition have not gone unnoticed. Research performed by Baranauskas et al. (1), indicated that ultrasound measurements for body composition have the accuracy of DEXA scans but the portability similarities of skinfold caliper measurements. Even though DEXA is the gold standard for assessing body composition, having access to a portable and inexpensive method to measure body composition can be very useful to athletes.

The BodyMetrix™ method utilizes A-mode ultrasound and Body View Professional Software (IntelaMetrix, Inc., Livermore, CA) to determine body composition and body fat percentage. The BodyMetrix™ consists of a wand (ultrasound transducer) that plugs directly into a computer. Ultrasound gel is placed on the wand and applied to the skin. The transducer is then moved over the measurement site and the subcutaneous adipose tissue thickness is recorded. The software uses the adipose tissue thickness measurement for each location to incorporate into the proper body density equation and obtain the estimate of overall body fat percentage. Training to use this method is minimal and the BodyMetrix™ is quick and efficient. The BodyMetrix™ is as portable as a skinfold caliper but decreases errors involving palpating the skin, improving inter- and intrarater reliability, and can measure adjacent muscle thickness as well as subcutaneous adipose tissue thickness (3). The BodyMetrix™ can utilize different measurement techniques, including both three- and seven-site techniques to determine body composition.

The values obtained from the three-site and the seven-site measurements are used in the Jackson-Pollock equations to determine overall body density. The Jackson-Pollock formula is a commonly used calculation that can be applied to a variety of populations to determine body density with the use of variables such as: three and seven-site measurements, age, and gender (1). The Body View Professional software uses a proprietary algorithm to convert the subcutaneous fat thicknesses obtained from the BodyMetrix™ BX2000 A-mode ultrasound to a BF% value (17). While the three-site measurement BodyMetrix™ technique is used to determine body composition, the seven-site measurement technique with the BodyMetrix™ is utilized more often, as it is thought to be a better representation of overall body composition (1).

Barreira (2013) discovered that the seven-site skinfold method with calipers is the most common method of body composition assessment (2). It is that a seven-site analysis provides a more accurate representation of overall body composition compared to the three-site because it incorporates subcutaneous adipose tissue values from more locations than the three-site estimation (1). While the seven-site is thought to be more accurate, there is a lack of research concerning the validity of the three-site measurement technique. Due to the lack of research, the purpose of this study was to determine if there is a difference in body fat percentage when comparing the three-site method and the seven-site measurement method with the use of the BodyMetrix™ . The independent variable was the type of testing technique used (three versus seven site) and the dependent variable was the body fat percentage value. The independent variables are the three-site and the seven-site techniques. It was hypothesized that the 3- and 7-site skinfold methods would yield difference in BF% when used as part of the BodyMetrix™.

METHODS

The research was carried out in accordance with the ethical standards of the International Journal of Exercise Science (11). A total of 40 female National Collegiate Athletic Association (NCAA) Division II athletes were recruited from teams at The University of Alabama in Huntsville for participation in this study. The participating athletes were from the volleyball (n = 8), soccer (n = 17), and softball (n = 15) teams. These participants all trained regularly with their respective sports teams and all athletes were free from injury during their time of participation. The inclusion criteria required participants to be NCAA Division II female collegiate athletic volleyball, soccer, or softball players. Exclusion criteria were those who did not follow the pre-testing guidelines (no eating, drinking, or exercise within 4 hours of testing). This study was approved by the university's Institutional Review Board prior to participation involvement. An a-priori power analysis (G*POWER 3.1.9.1,Universität Kiel, Germany) indicated a total of 30 participants were necessary for a power of .80, with an effect size of 0.5 and an $\alpha = 0.05$.

Protocol

The BodyMetrix™ (IntelaMetrix, Inc., Livermore, CA) ultrasound wand was calibrated on the day when testing was conducted, to ensure optimal accuracy of the BodyMetrix™ . Participants were asked to follow the same pre-testing guidelines, including no lotion or sweat on the skin prior to testing (2). The athletes arrived at the exercise physiology laboratory to meet with the researchers, where they were informed of all risks and benefits from participating in the study and signed an informed consent document. The participants were informed that the BodyMetrix™ is a newer method to assess body composition. All measurements were taken with shoes removed. Height was measured to the nearest 1-mm using a Seca Portable Stadiometer Height- Rod (213, Hamburg, Germany), and body mass was measured by a Befour (Fs-1000, Saukville, WI) incorporated mechanical scale to the nearest 0.01 kg (both measurements taken barefoot).

Following the collection of participant demographic data, body composition of the athlete was measured using the BodyMetrix™ with all measurements taken using the "athletic" preset on the device. All skinfold landmarks were denoted with a marker prior to either of the body composition analyses being conducted to ensure that the measurements sites would be replicated. Three- site and seven-site measurements for BodyMetrix™ were performed on all participants three times on each landmark, in revolving order from one spot to the next, and so on until all sites had been measured. The testing order was randomly assigned for each participant by flipping a coin to determine if the participant would start with the three-site or seven-site measurement.

IntelaMetrix has many ways to calculate body composition involving different formulas; for this study, the Jackson-Pollock (three-site and seven-site) equations were used to determine body density, which is used to determine overall BF% values. Both the three-site (triceps, suprailiac, and the thigh [13]) and seven-site measurements (triceps, subscapular, chest, axilla, abdominal, suprailiac, and thigh regions [16]) were taken for every participant by the same trained researcher to ensure proper intrarater reliability. Pilot testing (n = 12) revealed excellent test-retest reliability (ICC = .915 to .979) for our chosen evaluator. The measurements were all taken on the right side of the body per manufacturer guidelines (15). A reading was taken a total of three times at each site prior to moving onto the next anatomical location.

For each reading, ultrasound gel was placed onto the wand by the researcher and light pressure was used to apply the gel to the measurement site. It was essential that almost no pressure is applied, so that the skin is not compressed or altered, thereby possibly altering the reading at the measurement site (18). Each participant was allowed a 5-minute seated rest between sets of measurements.

Statistical Analysis
Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 25. Descriptive statistics were measured for age, height, body mass, and the type of sport played by the participants. Normality of the body composition measures were tested using the Shapiro-Wilk test. All values were normally distributed. A paired sample t-test was used to compare body composition of the three-site measurement to the seven-site measurement. Effect sizes (ES) were calculated using Cohen's d (4) for paired sample t-tests. For all statistical analyses, an alpha level of 0.05 was set *a priori*.

RESULTS

The overall BF% with the three-site formula (23.21 ± 3.61%) was significantly lower (t = -6.768, p < .001, 95% CI [-3.30, -1.78], d = 1.069) than the seven-site formula (25.75 ± 4.39%) using the BodyMetrix™. Participant descriptive characteristics are presented in Table 1. The three-site BF% for volleyball (21.79 ± 3.36), soccer (23.14 ± 3.40), and softball (24.05 ± 3.95) were all lower than the seven-site BF%. The seven-site BF% values for volleyball, soccer, and softball were 23.79% ± 3.45%, 25.75% ± 4.15% and 26.85% ± 4.95% respectively (see Figure 1). The average time it took to collect the three-site was 80 sec ± 0.10 sec and the average time to collect the seven-site measurements for BodyMetrix™ was 213 sec ± 0.02 sec.

Table 1. Participant Characteristics for NCAA Division II Female Collegiate Athletes

Variable	*M* ± *SD*
Age	20.10 ± 1.15
Height (cm)	167.10 ± 7.63
Weight (kg)	66.59 ± 7.64
Body fat % three-site	23.21 ± 3.61
Body fat % seven-site	25.75 ± 4.39

M ± *SD* = mean ± standard deviation. Volleyball (n) = 8, Soccer (n) = 17, and Softball (n)= 15.

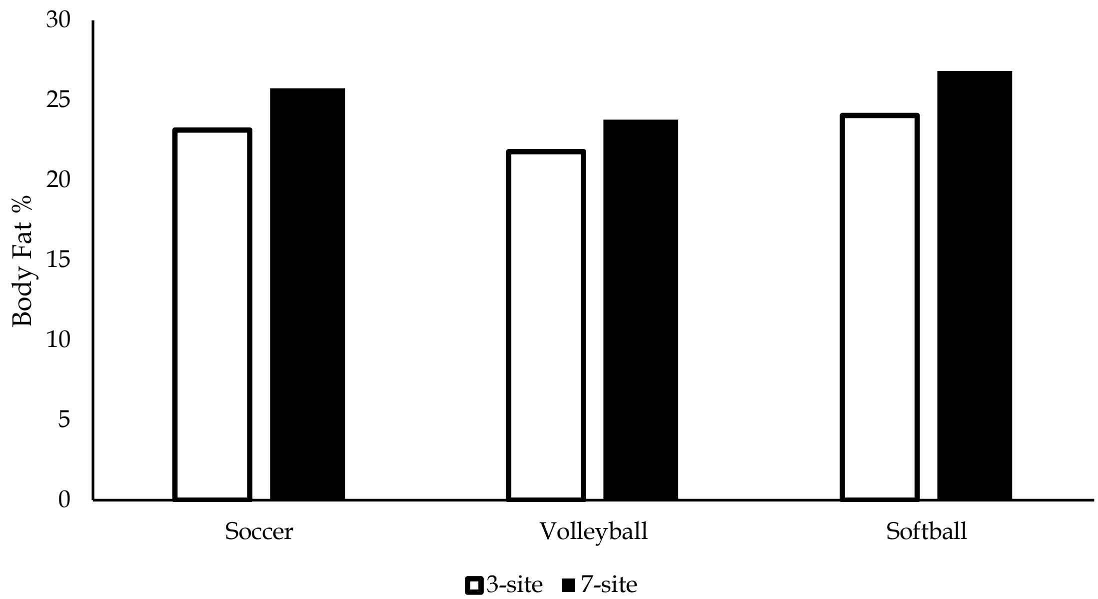

Figure 1. Differences in three-site and seven-site body fat percentage values by sport.

DISCUSSION

To our knowledge, limited investigations have compared the three-site BF% measurements against the seven-site BF% measurements using the BodyMetrix™ in female collegiate athletes. The three-site technique (23.21 ± 3.61) was found to be lower regarding body composition when compared to the seven-site (25.75 ± 4.39) technique, supporting our hypothesis.

On average, the three-site measurement took less time to complete than the seven-site measurement. The three-site measurement technique proved to be time efficient, reducing the overall duration to measure body composition by more than two minutes. Along with being faster to complete due to the ease of access to the testing sites, the three-site option can be very appealing to patients or athletes who are more reserved regarding removing clothing.

A reduced number of measurement sites could alter BF% accuracy, due to variation in body fat distribution (1). Baranauskas et al. (1) suggests a limitation of the three-site could be that the lack of sites may lead to inaccuracy when compared to the seven-site. Therefore, the seven-site measurement technique could be more representative of overall BF%. However, despite the potential for varying somatotypes across the three sports in the current study, BF% as measured by the three-site (p = .366) and seven-site (p = .286) methods was not significantly different across the three sports. This could indicate the differences between three and seven-site BF%, are due to the number of sites measured rather than the location.

Regarding analyzing differences between the three-site measurement and the seven-site measurement with the BodyMetrix™, other research has been done with similar variables and varying results. Results of a study performed by Baranauskas et al. (1) found significant differences between the Jackson-Pollock three-site and seven-site with the use of the BodyMetrix™. Specifically, the seven-site technique produced higher BF% in females than the three-site (1). These results (1) are similar to the findings of Wagner (17), which also indicated ultrasound was not as valid in regard to female athletes, but was when utilized with male athletes, which were not included in the population for this study. The A-mode ultrasound measurement technique overestimated BF% in the female athletes. A study by Beileiman (3), investigated the use of A-mode ultrasound (BodyMetrix™) to measure body composition on Brazilian adults. Subcutaneous fat thickness was measured at six-sites: the triceps, biceps, subscapular, abdominal, thigh, and calf regions. It was found that female's BF% were overrepresented by ~ 0.1%. The formulas and sites were not the same as used in the current study, with the use of the six-sites and other measurement applications, but ultrasound was found to be a reliable source (Lin's concordance correlation coefficient = 0.903) for determining BF% (3).

In our study, the results obtained from the seven-site and the three-site measurements were thought to be due to the differences among participants. The differences in softball, volleyball, and soccer place different physiological demands on the body. Exercise type and demand across the sports could result in differences in overall body composition and fat distribution. Due to the location of these sites, the sport played by the participant can have varying results based on the body shape demands that the sport requires (6). The seven-site method encompasses more locations measured on the body, and therefore is more indicative of whole-body fat distribution.

Limitations of the study could include differing athletic seasons. This study was conducted, and data was collected during the middle of spring season. Softball was in season, while soccer and volleyball were in off season. Previous research comparing differences in body composition in collegiate female athletes found varying results depending on the sport (14). For soccer, no difference was found between in season and off season, whereas there were differences for volleyball athletes (14). To add to this line of research, future researchers might also focus on additional seasonal differences in body composition in volleyball and soccer players. Also, there is not a current standardized protocol for ultrasound body composition, unlike body composition testing using skinfold calipers (1, 17). However, standardized procedures were followed as stated in other research and interrater reliability was maximized via usage of only one skinfold technician (17). This lack of standardized factors for ultrasound include optimal scanning frequency and distance or length of scan, while skinfold measurements using calipers have detailed anatomical placement, measurement technique, and pretesting guidelines (17). Research defining a specific ultrasound scanning protocol should be a primary focus of future investigators.

When comparing the three-site and seven-site measurements with the BodyMetrix™ for collegiate female athletes, it was found that there was a difference in body composition between the two testing methods. In addition to being faster, the three-site method may also be appealing to patients or athletes who are more reserved regarding removing clothing or exposing certain areas of the body for measurement. However, practitioners should understand the measurement limitations that may result from the use of the three-site, as our study indicated results from the three-site are significantly different from the seven-site. Along with this, the BodyMetrix™ is a cheaper method in comparison to the gold standard of body fat composition, which requires less user experience (3).

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