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Assessing Various Body Composition Measurements as An Appropriate Tool for Estimating Body Fat in National Collegiate Athletic Association Division I Female Collegiate Athletes

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Abstract **Purpose:** The purpose of the study was to determine if various convenient and cost affordable body composition techniques correlate well with more expensive "gold standard" instruments for measuring body composition in female collegiate athletes. **Methods:** Thirty-two Division I track and field and basketball female athletes participated in the study. The host university's Institutional Review Board approved the protocols towards ethical treatment of all subjects before the study commenced. Within one hour, each subject underwent body composition assessments via *air displacement plethysmography* (*ADP*), skinfold (SF) measurements, and bioelectrical impedance analysis (BIA). **Results:** No significant differences were found between basketball and track athletes thus data was normalized. No significant difference in calculated percent body fat was noted between ADP and SF ($p = .002$), but there was a significant difference between ADP and BIA ($p = .478$). Per Pearson correlations, moderate correlations existed between body fat percentages obtained by ADP and SF ($r = .689$) as well as between body fat percentages estimated by ADP and BIA ($r = .447$). **Conclusions:** Results indicate the SF technique had the highest correlation when compared to the BOD POD®. Skinfold measurements obtained with the Harpenden Skinfold Calipers may be used as a quick, affordable, and reliable technique for measuring body fat percentages in female collegiate athletes when performed by an experienced skinfold assessor.

Keywords: *body fat, air displacement plethysmography, skinfold,body composition*

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1. Introduction

Obesity is an excess accumulation of body fat and most health complications which arise from being obese are due to excess fat tissue, not from overall body weight [1]. Collegiate athletes need a reliable and cost affordable technique to assess body composition as many coaches are requesting measurements at different times throughout the season [2]. Hydrostatic weighting (HW) is considered to be the gold standard for calculating a person's body composition compared to other popular methods [3,4,5,6]. Other body composition techniques that hold the benchmark for accuracy include deuterium dilution, densitiometry, and dual-energy X-ray absorptiometry, also known as DEXA [7] but are considered costly or inaccessible for the typical college athlete. Air displacement plethysmography (ADP) has also yielded results similar to HW, indicating it may be used as a standard for comparison [4,5,6]. Techniques other than HW and DEXA, such as body mass index (BMI), waist-to-hip ratios (WHR), skinfold (SF) measurements, bioelectrical impedance analysis (BIA), and ADPwere developed because HW and DEXA are not suitable for all patients and can be time consuming [7,8,9,10]. Recently, BMI and WHR are not very popular measurement tools with Division One athletes in the United States. Many collegiate strength coaches and exercise specialists are using either SF through calibrated calipers or BIA to determine body composition. With hundreds of collegiateathletes at each institution, it would be wise to determine if any of these quick and current methods could be correlated to a laboratory tool such as HW or ADP.

2. Literature Review

2.1. Skinfold Technique

The SF technique can be performed at minimal cost, [11,12] provides quick results, does not require a lot of space or expensive equipment, is non-invasive [13], and can be administered to large groups of people. Skinfold measurements vary depending on the SF site, subject's obesity level, and the amount of tension placed on the skin [14]. Errors can also arise if the calipers are not placed in the exact location for consecutive measurements [15]. Inaccurate estimations of percent body fat can arise when equations which were developed for a specific population are applied to another group of people [13,16]. These factors may account for why Williams & Bale [13] noted a significant difference in predicting percent body fat between HW and the SF technique. However, Dixon et al. [5] found no significant differences in percent body fat estimated by ADP, SF, and HW. Additionally, Bentzur et al. [3] noted a high correlation (r = .85) between percent body fat estimated by SF and ADP.

The reliability and validity of the SF technique depends on multiple factors [9,11]. Both of these studies have shown when SF assessors were trained by an expert, more accurate results were obtained. Researchers have also suggested the type of SF caliper used may cause a difference in results [16]. Investigators obtained smaller SF measurements when they used either the Harpenden Caliper or Holtain Caliper when compared to either the Lange Caliper or the Adipometer but inter-rater reliability was greater when the Harpenden and Holtain Calipers were used.

2.2. Bioelectrical Impedance Analysis

Bioelectrical Impedance Analysis (BIA) has been commercially available since the 1980's. It is considered a popular tool to use based on the ease, accessibility, and portability of determining body fat percentage (Prentice & Jebb, 2001). The Body Stat™ is a type of BIA that measures an individual's body composition. The Body Stat™ has been shown to be a quick method that requires little training in determining body composition [8]. The Body Stat™ sends multiple frequency waves throughout the body to determine body composition which includes: fat mass, lean body mass, and total water composition [17]. According to Fornetti et al. [10] there was high reliability in a single trial of the BIA, indicating one trial with the BIA is sufficient. Results have been mixed regarding BIA as Biaggi et al. [4] found no significant differences in estimating percent body fat between ADP and HW or BIA, however, Williams & Bale [13] noted a significant difference did exist in predicting percent body fat between HW and BIA. Also, one previous study did note that leg-to-leg BIA predicted percent body fat significantly lower when compared to HW [5].

2.3. Air Displacement Plethysmography

Research studies have shown no significant differences in estimating percent body fat when comparing HW to ADP [4,5] or DEXA [2]. Dixon et al. [5] observed Division III collegiate wrestlers and found no significant difference between HW, ADP, or SF when estimating body composition. According to Biaggi et al. [4] percent body fat assessed by ADP and by HW was similar to previously reported validation studies. When comparing ADP to DEXA, ADP has been found to be a reliable and valid technique in measuring body composition in female collegiate athletes [2]. In further support, Bentzur et al. [3] discoveredhigh correlational values between body fat percentage measured by ADP and HW incollegiate track and field female athletes. Therefore, ADP could be identified as a valid and reliable method to compare other body fat percentage methods in collegiate female athletes.

2.4. Purpose

The purpose of the study was to determine if various convenient and cost affordable body composition techniques correlate well with more expensive "gold standard" instruments for measuring body composition in female collegiate athletes. It was hypothesized that the Body Stat™ machine is a reliable, valid, convenient, and cost effective tool in which percent body fat will highly correlate with BOD POD® results, in comparison to skinfold calipers used to assess percent body fat.

3. Methods

3.1. Subjects

This study was a quasi-experiemental prospective study design that utilized a sample of convenience. Inclusion criteria included: National Collegiate Athletic Association (NCAA) Division I female collegiate athletes over the age of 18. Exclusion criteria included: student athletes not associated with the research university, non-athletes, club team athletes, males, individuals under the age of 18, or anyone who was pregnant, had a history of cancer, hadelectrical or metal implants, or had a psychosocial fear of electricity. After insuring that the subjects met all inclusion criteria, 19 track athletes and 13 basketball athletes participated in the study. The mean age was 19.53 years with a range of 18-22 years.

3.2. Instruments

A calibrated stadiometer was used to measure height and a standard tape measure was used to measure waist and hip circumference measurements. An electronically calibrated BOD POD® (Life Measurement Inc., Concord, CA) scale was used to measure weight. The BOD POD® Gold Standard Model number BOD POD® 2007A was used to assess percent body fat. The Quads can 4000 Version 4.08 (Body Stat™, British Isles, UK) was used to assess the athletes' hydration status, WHR, BMI, and percent body fat. Harpenden Skinfold Calipers (Baty International, West Sussex, UK) were used to estimate body composition because they have been found to have high inter-rater reliability [16].

3.3. Procedures

The study was approved by the Institutional Review Board at the host university. All protocols and procedures were reviewed by the IRB to ensure ethical treatment of all subjects during the study. The subjects for the study were recruited by the athletic training staff at the university. Informed consent was obtained upon arrival and time was allotted for participants to ask questions. Individuals that desired to participate were given a unique identifier number. Subjects were advised to drink an

appropriate amount of water 24-48 hours in advance to ensure proper hydration and to refrain from exercise and food consumption one hour prior to testing. They were also instructed to wear compression shorts and a sports bra or a two piece swimsuit. Testing was performed over a two day period and each athlete had all tests performed within one hour.

Height and weight measurements were taken by the same examiner and recorded to the nearest ¼ inch and thousandth of a pound, respectively. Waist circumference measurements were taken at the top of the iliac crest and hip circumference measurements were taken at the level of the greater trochanters by the same examiner and were recorded to the nearest ¼ inch. The BOD POD® was calibrated according to manufacturer's guidelines. Subjects were asked to remove all jewelry and wear a Lycra swim cap. Subjects also wore either compression shorts and a sports bra or a two-piece bathing suit. The on-screen testing procedures were followed in accordance to the BOD POD® manual. The Siri equation was used to estimate body fat percentage based upon the density obtained by the BOD POD®. The BOD POD® Operator's Manual recommended that this equation be used for the general population, as the subjects included both Caucasian and African American females. Thoracic gas volume was estimated and participants were instructed to remain as still as possible during testing. The temperature, barometric pressure, and relative humidity were maintained within the specified ranges for proper operation of the BOD POD®: 70.5 – 71 degrees F, 29.8 – 29.9 inches, and 51.0 – 51.2% respectively. A printout of the BOD POD® results were given to the athlete and to the athletic trainer or the athlete's coach, based on the signed HIPAA release form.

The Body Stat™ was calibrated prior to testing according to the manufacturer's guidelines [17]. The subject's height, weight, age, gender, activity level, and waist and hip measurements were entered into the Body Stat™ machine. The highest activity level was selected for all subjects. The athlete's skin on the right side of the body was cleaned with an alcohol wipe and electrodes were placed at the following locations: on the dorsum of the hand proximal to the metacarpophalangeal joint, on the dorsum of the hand distal to the wrist joint, on the dorsum of the foot proximal to the metatarsophalangeal joint, and on the dorsum of the foot between the medial and lateral malleoli on the right side of the body. The red lead was placed on the more distal electrode of each limb and the black lead was placed on the more proximal electrode. The subjects were supinein anatomical position for three minutes before testing was performed. All Body Stat™ testing was completed by the same researchers.

The Harpenden Skinfold Calipers were calibrated before testing. Two SF measurements were taken within 15 seconds of each other on the right side of the body at the triceps, suprailiac, and thigh anatomical sites, using the average of the two measurements. The Jackson / Pollock equation was used to estimate body composition. All measurements were completed by an experienced assessor with 25 years of experience and SF certification through the American College of Sports Medicine, Cooper's Institute of Aerobic Research, and National Strength and Conditioning Association.

3.4. Data Analysis

Data was analyzed via Statistical Package for the Social Sciences 19.0. Frequencies and descriptive statistics were used to analyze demographic information including: age, height, weight, waist circumference, hip circumference, BMI, WHR, total body water, total weight, and body fat percentage estimated by BIA, ADP, and SF. No significant differences were found between track and basketball athletes, thus results were combined for the purposes of this study. Paired t-tests were computed to determine if significant differences existed between ADP when compared to BIA and SF. Pearson Correlations were used to analyze the relationships between the body fat percentages obtained by ADP, SF, and BIA.

Table 1. Descriptive Statistics (n = 32)

Variables	Minimum	Maximum	Mean	Standard Deviation
Age (years)	18.00	22.00	19.56	1.16
Height (inches) *	61.00	74.50	67.10	3.17
Height (cm) *	151.90	189.20	170.40	8.10
Weight (kg) *	109.26	191.28	145.45	21.73
Waist (inches)	25.50	36.25	29.37	2.62
Waist (cm)	64.80	92.10	74.60	6.70
Hip (inches)	22.50	43.00	36.13	3.33
Hip (cm)	57.20	109.20	91.80	8.50
BMI	17.50	29.00	22.48	2.52
WHR	0.73	0.88	0.81	0.03
BOD POD (% BF)	13.50	30.80	22.03	4.14
BIA (% BF)	11.30	27.80	19.57	3.68
SF (% BF)	12.30	34.70	21.50	5.69
TBW (kg)	49.80	61.30	55.19	3.38
Total Weight (kg)	109.30	191.30	146.02	21.43

BMI = body mass index; WHR = waist-to-hip ratio; BIA = bioelectrical impedance analysis; SF = skinfold; % BF = percent body fat; TBW = total body water

Table 2. Correlation and P-value between Body Composition Methods to the Bodpod

Bodpod comparison to other body composition methods	Correlation (r)	p-value
ADP to BIA	.447	.010
ADP to SF	.689	.000

ADP = air displacement plethysmography; BIA = bioelectrical impedance analysis; SF = skinfold

4. Results

The study included 32 female subjects between the ages of 18 to 22 years. This study had 100% retention rate and all subjects' data was included in the data analysis. Additional descriptive statistics can be found in Table 1. No significant differences were found between basketball and track athletes, therefore the data was normalized. Paired t-tests yielded a significant difference between percent body fat obtained by ADP and BIA (p = .002), however, no significant differences was found between ADP and SF (p = .478). Per Pearson correlations, moderate correlations [18] existed between body fat percentages between ADP and SF (r = .689). Low correlations (Carter RE, 2011) existed between percent body fat percentages estimated by ADP and BIA (r = .447).

5. Discussion

The current study found no significant difference (p = .478) in percent body fat estimated by the SF technique, when compared to ADP, but a significant difference (p = .002) was noted between body fat percentages estimated by BIA and ADP. Due to the fact that ADP has yielded body composition measurements similar to HW [3,4,5], the current study both contradicts and supports a study conducted with collegiate female athletes by Williams & Bale [13]. In contrast to the findings of the current study, These same authors noted significant differences in predicting percent body fat between HW and the SF technique. In support of the findings of the current study, Williams & Bale [13] also found a significant difference between HW and BIA. The current study contradicts the findings by Biaggi et al. [4] in which no significant differences in estimating percent body fat was found between ADP and HW or BIA.

On the other hand, this current study supports the results by Dixon et al. [5] who found no significant differences in percent body fat estimated by ADP, SF, and HW. Although the current study yielded a moderate correlation [18], between percent body fat estimated by SF and ADP (r = .689), the results parallel the trend found by Bentzur et al. [3] who noted a high correlation (r = .85) between ADP and SF. The current study revealed a 2.46% mean difference in fat free mass between ADP and BIA, which is similar to the results noted by For netti et al. [10] who found a 2% difference in fat free mass between DEXA and BIA in collegiate female athletes. The current study is also in agreement with the findings of Kispert et al. [15] in that percent body fat estimated in young athletes with the SF technique was more accurate when compared to ADP.

Based on the results of the current study, BIA may not be an appropriate measurement for estimating body composition for female college athletes. For collegiate programs that want a valid, reliable, cost effective, portable, and minimally invasive instrument to assess body composition in female athletes, the current study would support use of Harpenden Skinfold Calipers over other instruments. However, a skilled assessor, or an assessor who has been trained by an expert, would be highly recommended to perform SF measurements. Future studies on a non-athletic population are needed to determine if these results also apply to the general population.

5.1. Limitations

Possible limitations may include errors in height, although these errors were limited by using a standardized protocol and by having the same assessors perform the same measurements each time. Another possible limitation was that all athletes were females from a public Midwestern university and the majority of subjects were Caucasian. Another noted limitation of the study was the Body stat's programming limits with regards to rounding to the nearest standard unit.

6. Conclusion

It was originally hypothesized that the Body Stat™ machine is a reliable, valid, convenient, and cost effective tool in which percent body fat will highly correlate with ADP results, in comparison to other methods used, to assess percent body fat in female collegiate athletes. The results of this study demonstrate that Body Stat™ may not be the most appropriate technique to use on collegiate female athletes when assessing body compositionas they had low correlations in comparison to the BOD POD®. Specifically, the Body Stat™ had significantly different results when compared to the BOD POD®. However, SF measurements, using Harpenden Skinfold Calipers was shown to have the highest percent body fat correlation and revealed no significant difference when compared to the BOD POD® if performed by an expert assessor with years of experience.

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