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# COMPARISON OF BODY COMPOSITION TECHNIQUES TO DETERMINE BODY FAT IN HIGH SCHOOL WRESTLERS

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## ABSTRACT

**Brown DB, Mackenzie JE, Dennis KK, Cullen RW.** Comparison of Body Composition Techniques to Determine Body Fat in High School Wrestlers. ***JEP****online* 2006;9(3):24-32. Rapid weight loss has been a dangerous behavior associated with the sport of wrestling. The objective of this study was to examine the effectiveness of five body composition assessment techniques at determining body fat percentages in high school wrestlers. Eighteen male wrestlers (mean ± SD) [age: 16.2 ± 1.4 years; height: 171.9 ± 6.3 cm; mass: 74.1 ± 20.3 kg, % body fat 14.0 ± 6.7 %] participated in the study. All testing was completed during a single session with the wrestlers reporting to the laboratory having fasted and restricted fluid intake for four hours prior to testing. Height and weight were obtained followed by five different body composition assessment techniques: Underwater Weighing (UWW), Air Displacement Plethysmography (ADP), Bioelectrical Impedance (BIA), 3 site skinfold (3SK) and 6 site skinfold (6SK) analysis. No significant differences existed between the five testing methods ($p$ = 0.297). Pearson correlations ranged from 0.989 to 0.805 ($p \leq 0.05$) between UWW, ADP, 3SK and 6SK analyses. These data suggest that % BF may be successfully estimated in high school wrestlers by using ADP, UWW, 3SK and 6SK analyses providing that the same testing procedure is used on the same athlete throughout the season.

**Key Words**: Weight Cutting, BodPod, Underwater Weighing, Bioimpedance, Skinfold

## INTRODUCTION

Rapid weight loss, or "weight cutting," has been a dangerous behavior frequently associated with the sport of wrestling (1,14,15). This behavior has aroused concern in the medical community as early as the 1930's (9). In order to combat unsafe weight loss practices, the American College of Sports Medicine (ACSM) has reissued its position stand that calls for the enactment of regulations to limit weight loss among wrestlers. In compliance with the ACSM, the National Collegiate Athletic Association (NCAA) has issued its own sets of rules and regulations that prohibit unhealthy weight loss practices. The wrestling weight certification program (WCP) requires that each NCAA member institution have a qualified examiner carry out an initial weight assessment using body weight, body composition and the specific gravity of urine. A calculation consisting of the wrestler's fat free mass (FFM) in combination with 5% body fat (%BF) is then used to determine a minimum wrestling weight (1,10,17,18). Along with the NCAA, the National Federation of State High School Associations (NFHS) supports the implementation of rules that promote weight control, and has proposed that all state high school athletic associations implement a WCP similar to the NCAA's (1,9).

While it is recognized that UWW and SK assessments are considered acceptable methods for assessing body composition, it has recently been questioned whether other valid techniques such as bioelectrical impedance analysis (BIA) and air displacement plethysmography (ADP) may be accurately used for determining minimum wrestling weight. Even as UWW is well established, it should be noted that repeated submersion while maximally exhaling can be problematic for many subjects. There is also a need for technical expertise to ensure accurate measurements to promote the validity of the test. SK assessment is also dependent upon examiner reliability, as well as population specific equations to determine valid outputs (17,18). The use of these equations raises concern when dealing with the wrestling population. Using formulas not validated within the wresting population can lead to error and potentially lead to a health risk. A false high % BF can be calculated, thereby allowing an athlete to lose an unsafe amount of weight. Conversely, a false low % BF may inhibit a wrestler from losing weight when weight loss is warranted. An accurate means of evaluation of body composition that requires less technical skill and minimizes examiner bias such as ADP would be beneficial to include in weight control programs (4,5,17,18).

The BOD POD® Body Composition System (Life Measurement Inc., Concord CA) was designed to use ADP to efficiently estimate % BF with minimal expertise in comparison to UWW. Similar to UWW, ADP is a densitometric method that is dependent upon the measurement of mass and volume to calculate body density ($D_b$). Dempster et al., 1995 (5) provide a detailed explanation of the methodology elsewhere. The BOD POD® can be viewed as advantageous due to the fact that it requires less technical skill than UWW and uses air instead of water which provides the subject with a more comfortable testing environment (4,5,17,18). Previous literature indicates that comparison studies between UWW and ADP demonstrate an agreement of measures in $D_b$ and subsequently %BF (17) whereas others have found greater discrepancies (4). Differences may be attributed to variations of testing protocol, study designs and subject characteristics. Air displacement plethysmography testing in the athletic population has occurred in NCAA Division-I football players, wrestlers and female athletes. Collins et al. (4) declared ADP measurement of mean % BF to be 1.9% higher than UWW in NCAA Division-I football players, where as Utter et al. (17) recently demonstrated that $D_b$, %BF, and FFM measures determined by ADP were not statistically significantly different when compared with the UWW values of collegiate wrestlers. There are little data on the reliability and validity of ADP in the athletic population. No previous studies have been published evaluating ADP in a high school wrestling population.

The purpose of this study was to determine the effectiveness of body composition techniques at determining body fat percentages in high school wrestlers. UWW was selected for comparison due to its status as the criterion for the NCAA WCP, as well as its acceptance as the gold standard throughout the scientific community. SK assessment was selected due to its frequent use as a tool for body composition estimation in wrestling as well as its relative low cost and simplicity which makes it the chosen method for most high school athletic associations. Bioelectrical impedance was included for comparison due to its previous use as a method for determining minimal weight in wrestlers as well as its ability to be used in diverse settings. It is hypothesized that there would be no significant differences between ADP and UWW for $D_b$ and % BF therefore showing ADP to be an acceptable method for determining minimum wrestling weight in high school wrestlers.

## METHODS

### Subjects

Eighteen male wrestlers from two central Illinois IHSA (Illinois High School Association) Class A high schools participated in the study during the 2002-2003 season. The physical characteristics of the subjects are presented in Table 1. Subjects and their parents/guardians gave written informed assent/consent; for their involvement in this study using forms that were reviewed and approved by the Institutional Review Board.

### Procedures

All testing was completed during a single session for each school with the subjects reporting to the laboratory having fasted and restricted fluid intake 4-h prior to testing. Subjects were instructed to void the bladder and bowels before testing. Height and weight were obtained using a standard scale. Skinfold analysis and BIA were performed as initial assessments. Next, pulmonary function analysis was made for the estimation of residual lung volume from vital capacity. BOD POD® analysis was then performed with lung volumes measured and predicted using the BOD POD® system. Lastly, each subject completed UWW immediately following BOD POD® assessment. Due to the relevancy of hair and clothing on the BOD POD® measurements, the subjects wore Spandex shorts and a swim cap to eliminate excess air pockets.

### Skin Fold Analysis

Double thickness subcutaneous skinfold (SK) measures were taken using Lange calipers adhering to the 3-site and 6-site methods commonly used for the estimation of minimal wrestling weight (10, 16). Anatomical landmarks measured for the 3-site and 6-site techniques consisted of: triceps, subscapular, abdomen, and chest, triceps, subscapular, abdomen, suprailiac, and thigh, respectively. All SK measurements were made by the same investigator throughout the study. Skinfolds were measured 3 times at each site to the nearest 0.5 mm with the mean recorded. Measurements were taken on the right side of the body. The 3 site SK measurements were used to estimate body density (Db) from the Lohman prediction equation (Db (g/cc) = 1.0973 – 0.000815 x (sum of 3SK) + 0.00000084 (sum of 3SK)$^2$) (10). Subsequently percent body fat was then determined using the Brozek equation. The 6 site SK measurements were used to estimate body fat (BF) from the Tipton & Oppliger prediction equation (BF = 0.148 x (chest SK) + 0.075 x (subscapular SK) + 0.077 x (triceps SK) + 0.160 (suprailiac SK) + 0.152 x (abdomen SK) + 0.102 x (thigh SK)) (16).

### Bioelectrical Impedance Analysis.

Bioelectrical impedance measurements were obtained by using the Bioanalogics Bioelectrical Impedance Analysis System (Bio/Analogics, Beaverton, OR). Four electrodes were attached in accordance to the manufacturer's instructions to the dorsal surface of the hand and anterior surface of the ipsilateral foot. Subjects were measured lying in a supine position on a nonconductive table. Measures were repeated three times with the average of the reading recorded as the impedance value. Following the measurement of bioelectric impedance percent body fat was determined using the manufacturer's provided software.

**Bod Pod®**

To ensure accuracy, the BOD POD® was calibrated before each test using a 50L calibration cylinder at volumes of 0 and 50 L according to manufacturer's instructions. Subjects were tested wearing spandex shorts and swim cap to compress their hair. Before entering the chamber, subjects were weighed on a calibrated digital scale to the nearest 5g (5). A two-point calibration was then initiated. The subject then entered the BOD POD® for testing. Once two consistent measures of body volume were achieved, thoracic gas volume ($V_{TG}$) was then measured. Thoracic gas volume was measured during the testing procedure. A more complete explanation of equipment design and operating procedures are outlined by Dempster et al (5). Density was determined using BOD POD® calculated body volume and mass. Density was used to predict % BF using the Siri equation.

**Underwater Weighing**

Prior to UWW, residual lung volume was predicted using a measurement of vital capacity. Vital capacity was obtained using the Vitalograph PFT II Plus Spirometer (Kansas City, KS). Subjects were instructed to forcefully and expediently expel as much air as possible when using the spirometer. Three maximal forced expiratory maneuvers were performed, and the best forced expiratory flow curve was recorded and subsequently used for data analysis. Residual volume (RV) was estimated as a percentage of the measured vital capacity. Estimated residual volume was used in conjunction with UWW for the determination of body composition. Underwater weighing was performed using the Novel Hydrostatic Weighing Analysis System. Each subject was weighed while seated on a chair attached to a Chatillion autopsy scale, and instructed to expel as much air as possible from his lungs during complete submersion. It was at this point that the underwater weight of the subject was acquired. A total of 5 to 12 trials were recorded, with the heaviest underwater weight measurement used in the determination of body density. The estimated RV was also used in the determination of body density. The body density value was then entered into the Siri equation to estimate percent body fat.

**Statistical Analyses**

Data were analyzed using SPSS 11.0 for windows (SPSS Inc., Chicago, IL) and Microsoft Excel for windows (Microsoft Corp., Seattle, WA). Values are expressed as means $\pm$ SD. A one-way ANOVA was performed to detect significant differences in % BF among the five testing methods (ADP, UWW, 3-SK, 6-SK and BIA). Pearson correlation coefficients were computed. Linear regression analyses were performed with % BF by UWW as the dependent variable to decide whether the regression line differed significantly from the line of identity. An alpha level of $p<0.05$ was used for significance testing.

## RESULTS

The characteristics of the subjects are presented in Table 1. The sample consisted of 18 male wrestlers from two central Illinois Class A High Schools. Percent body fat results are presented as means in Figure 1. The results of a one-way ANOVA indicate no significant difference among the five testing methods ($p = 0.297$).

A Pearson correlation demonstrated that the strongest relationship among testing measures exists between the BOD POD® and UWW ($r = 0.893$) (Table 2). Similar strengths are demonstrated when UWW is compared to 3 site ($r = 0.864$) and 6 site SK analysis ($r = 0.885$). Conversely, a moderate correlation is seen between UWW and BIA ($r = 0.587$). Indicating that BIA produces a lower validity and is less successful when compared to the criterion measure of UWW. It should be noted that a moderately strong correlation ($r = 0.738$) exists between 3 site SK and BIA. Three site SK analysis is also accepted as a criterion measurement.

**Table 1. Descriptive data of the subjects.**

| *Variable* | *Mean (± s.d.)* | *Range (minimum-maximum* |
|---|---|---|
| ***Age (yrs)*** | 16.2 ±1.4 | 14 - 18 |
| ***Height (cm)*** | 171.9 ±6.3 | 161.0 - 182.0 |
| ***Weight (kg)*** | 74.1 ±20.3 | 48.7 - 115.3 |
| ***Percent Body Fat (via Underwater Weighing)*** | 14.0 ±6.7 | 4.4 - 28.0 |
| ***Fat Mass (kg)*** | 11.9 ±8.4 | 4.0 – 30.3 |
| ***Fat Free Mass (kg)*** | 62.2 ±14.2 | 40.5 – 88.3 |

Similar results can be seen in Figure 2. Linear regression results indicate a moderately strong agreement between UWW and ADP, 3 site and 6 site SK analyses. However, the slope of the regression lines differed significantly from 1.0 and the intercepts differed from 0 in BIA, 3 site and 6 site SK analyses ($p < 0.05$). The strongest relationship was seen between UWW and ADP ($r = 0.893$). In this instance the slope of the regression line differed significantly from 1.0 ($p < 0.05$), whereas there was no significant difference detected from the intercept of 0 ($p = 0.429$). The weakest relationship can be seen between UWW and BIA ($r = 0.587$).

**Table 2. Pearson Correlation Matrix**

| | BOD POD® | UWW | 3 Site SF | 6 Site SF | BIA |
|---|---|---|---|---|---|
| BOD POD® | 1.0 | | | | |
| UWW | 0.893 | 1.0 | | | |
| 3 Site SF | 0.805 | 0.864 | 1.0 | | |
| 6 Site SF | 0.859 | 0.885 | 0.989 | 1.0 | |
| BIA | 0.627 | 0.587 | 0.738 | 0.783 | 1.0 |

## DISCUSSION

This investigation evaluated the effectiveness of body composition techniques at determining body fat percentages in high school wrestlers. An important factor to recognize in this study is the subject population. With the impending implementation of weight certification programs at the high school level there is no previous research published on the use of ADP in high school wrestlers, making this study unique. The most significant findings of this study indicate that % BF measured by ADP did not differ statistically from UWW or 3 site SK analysis. This finding is quite significant since both UWW and 3 site SK analysis are criterion measures for weight certification programs. These results would suggest that ADP could be considered a criterion measure for high school weight certification programs.

A curious finding in this study is the comparison of ADP to 6 site SK analysis. While no statistical difference exists between the two measures, an anthropometrical difference of 4.88% body fat can be seen, suggesting that 6 site SK underestimates %BF. A value of 4.88% body fat could mean the difference between a healthy individual and one who is at risk for health complications. To make this data applicable to the wrestling world, a false low % BF may inhibit a wrestler from losing weight when weight loss is warranted. When evaluating these data it should be taken into consideration that while different body composition testing techniques may demonstrate differences among the means, validity and consistency must also be evaluated. For example, a testing measure with a high correlation would indicate validity where as a testing measure with a high $r^2$ value and low SEE would signify consistency. Therefore, since ADP and UWW are strongly correlated ($r = .893$) and no

significant differences in % BF are seen between ADP (14.83%) and UWW (14.04%), APD can be considered a valid testing measure. While no statistical differences were seen between the five measures, significant anthropometrical differences were noted when 6 site SK analysis (9.95%) was evaluated against UWW. However, its validity was shown by its strong correlation ($r$ = .885). Its consistency is promoted by its moderately strong $r^2$ value and relatively low standard error of estimation ($r^2$ = 0.7827, SEE = 3.219%). It may be inferred that 6 site SK analysis will produce consistently lower values of %BF in comparison to UWW. If this testing measure were to be used in weight control programs then it must be used on the same athlete throughout the season so that his minimum wrestling weight would remain consistent.

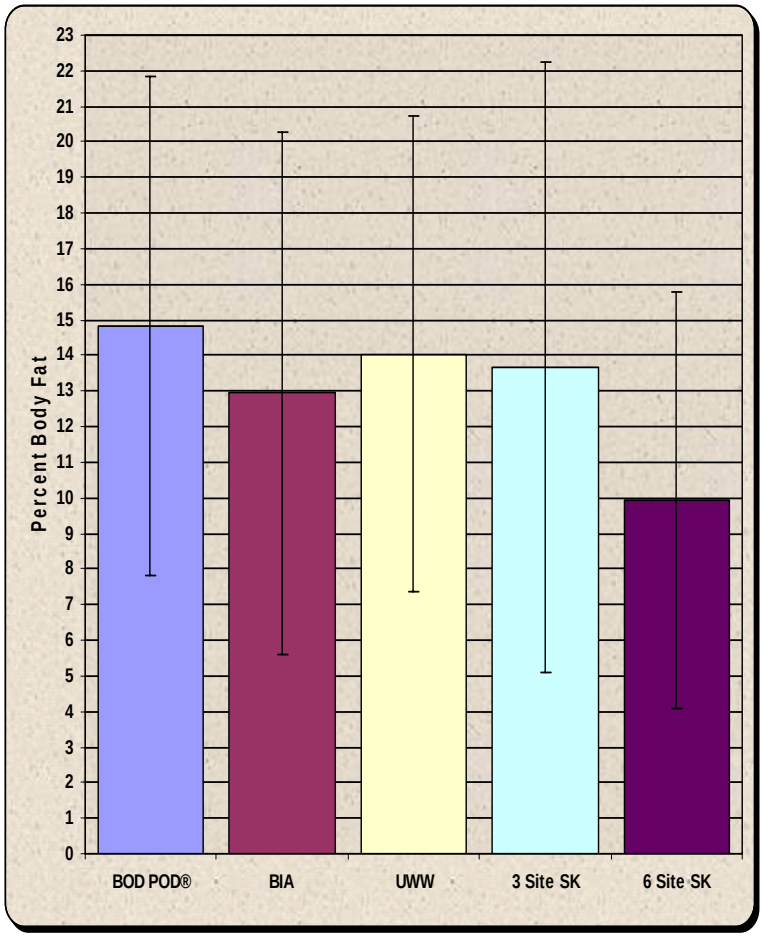


**Figure 1. Mean percent body fat in High School Wrestlers determined by different body composition techniques. No significant difference ($p$ = 0.297)**

Although 6 site SK analysis produced a lower mean in comparison to UWW and ADP, it is still a valid test. While 6 site SK analysis is consistent; it is recommended that the 3 site SK analysis be used as the primary assessment tool in high school weight certification programs. The use of the Lohman equation is preferred since it has endured the examination of previous cross-validation studies in NCAA wrestlers as well as high school wrestlers (2,3,9,10,13,17). Not only is the associated equation preferable, but 3 site SK assessment would be ideal for many high school weight certification programs due to its relatively low cost and simplicity.

Previous studies as well as this investigation have utilized UWW as the criterion method. Using densitometry in wrestling may have its limitations based on the assumption that hydration and density of the fat-free mass remain consistent. As it has been repeatedly documented, unsound weight loss techniques such as dehydration are seen as a cultural norm in the sport of wrestling. Wrestlers may also be well advanced in muscular development in comparison to the non-athletic population within their matched age group thus altering their density (2). Although wrestlers may have an increase in muscle mass, it should be noted that children and adolescents may have a higher percentage of water in their fat free body therefore resulting in a lower density than that of adults (2). These reductions in $D_b$ may impact the validity of body composition assessment techniques.

Due to these extrinsic factors, hydration must be standardized during testing. This study attempted to control hydration by prohibiting subjects fluid and food intake 4-h prior to testing. While this method is subject to subject compliance, it should be noted that the schools participating in this study are seeking to implement a WCP into their programs; therefore adherence to protocol was monitored and enforced by the coaching staff. Although this study did not assess the specific gravity of urine, results

concerning ADP are in agreement with the findings of Utter et al., 2003 (17). Utter et al. recently demonstrated that $D_b$, %BF, and FFM measures determined by ADP were not statistically significantly different when compared with the UWW values in both a hydrated and dehydrated state in collegiate wrestlers.

In contrast to previous research and this study's findings regarding ADP, Collins et al. (4) found when evaluating Division I football players % BF determined by ADP (15.1%) was significantly lower than when determined by UWW (17.0%). Research reflecting the validity of APD on children also produces mixed results (6,7,8,12). Fields et al. (8) reported that on average, the BOD POD® gave significantly different % BF than UWW. They also report a SEE of 3.3% which is only in the good range for test consistency. Other studies examining children (6,12) reported that ADP measures of % BF are usually higher than the measurements produced by UWW, but did not declare them significantly different.

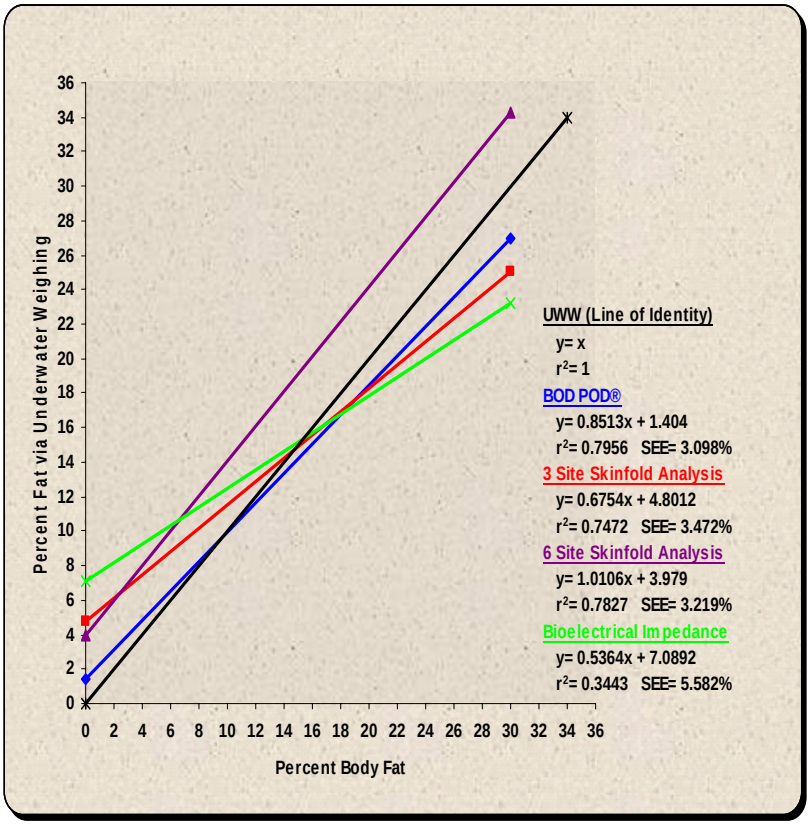


**Figure 2. Agreement between percent fat in High School Wrestlers determined by different body composition techniques.**

While the primary focus of this study was evaluating the validity of ADP in comparison to criterion measures such as UWW and SK, BIA was also considered. This study does not demonstrate the validity of BIA. While the difference in mean % BF only differed 1.89% from UWW, BIA only produced a moderate correlation (r = 0.587) with UWW. Regression analysis also indicated that BIA was an inconsistent testing measure ($r^2$ = 0.3443, SEE = 5.58%) by demonstrating a significant deviation from the line of identity. The results of this study indicate that at a low adiposity BIA underestimates % BF, however, as adiposity increases in a subject, BIA becomes more likely to overestimate % BF. There is limited research available in on the use of BIA for body composition assessment in high school wrestlers. Caution should be exercised before accepting BIA as reliable method for assessing % BF in any WCP. As noted with densitometry, hydration is a key factor in influencing the results. Variations in water content from exercise, dehydration, and fluid restriction must be standardized before using BIA (2,18).

The findings of this study may be added to the increasing volumes of research examining the validity of measuring % BF in ADP compared to UWW (4-8,11,12,17). This study demonstrated that % BF may be successfully measured in high school wrestlers by using ADP. The BOD POD® can be viewed as advantageous due to the fact that it requires less technical skill than UWW and uses air instead of water which provides the subject with a more comfortable and reliable testing environment. This technology can be used to compute minimum wrestling weight in a safe and relatively quick and accurate manner.

While different body composition testing techniques may demonstrate significant differences among the means, consistency must also be evaluated. Additionally, while these measures are considered

appropriate, it should be noted that recommendations based off this study are from a small number of wrestlers with a large variance of body composition. This study included data from all weight classes, which could account for variances in standard deviations as well as discrepancies within mean % BF. Future research should include the evaluation of %BF within each weight class as well as the inclusion of the athlete's hydration status. In this particular study it was discovered that while 6 site SK analysis differed significantly in mean % BF but it is still viewed as a consistent testing measure. Therefore its use, as well as UWW, ADP and 3 site SK analysis would be appropriate for minimum wrestling weight calculations provided that the procedure is used on the same athlete throughout the season. It is recommended that ADP, UWW and 3 site SK assessments should each be considered valid testing procedures for calculating minimum wrestling weight in high school wrestlers.

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