

Evaluation of Ultrasound in Assessing Body Composition of High School Wrestlers

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ABSTRACT

UTTER, A. C., and M. E. HAGER. Evaluation of Ultrasound in Assessing Body Composition of High School Wrestlers. *Med. Sci. Sports Exerc.*, Vol. 40, No. 5, pp. 943–949, 2008. **Purpose:** To evaluate the accuracy of ultrasound (ULTRA) in assessing fat-free mass (FFM) in comparison with hydrostatic weighing (HW) and skinfolds (SK) in high school wrestlers in a hydrated state. **Methods:** Body composition was determined by ULTRA, HW, and three-site SK in 70 high school wrestlers (mean \pm SD: age, 15.5 \pm 1.5; height, 1.60 \pm 0.08 m; body mass, 65.8 \pm 12.7 kg). For all methods, body density (D_b) was converted to percent body fat (%BF) using the Brozek equation. Hydration state was quantified by evaluating urine specific gravity. **Results:** There were no significant differences for estimated FFM between ULTRA (57.2 \pm 9.7 kg) and HW (57.0 \pm 9.9 kg); however, SK (54.9 \pm 8.8 kg) were significantly different from HW. The standard errors of estimate for FFM with HW as the reference method were 2.40 kg for ULTRA and 2.74 kg for SK. Significant correlations were found for FFM between HW and ULTRA ($r = 0.97$, $P < 0.001$) and between HW and SK ($r = 0.96$, $P < 0.001$). A systematic bias was found for SK, as the difference between SK and HW significantly correlated with the FFM average of the two methods ($r = -0.38$, $P < 0.001$). This systematic bias was not found for ULTRA ($r = -0.07$). **Conclusions:** This study demonstrates that ULTRA provides similar estimates of FFM when compared with HW in a heterogeneous high school wrestling population during a hydrated state. ULTRA should be considered as an alternative field-based method of estimating the FFM of high school wrestlers. **Key Words:** WRESTLING, FAT-FREE MASS, MINIMUM WRESTLING WEIGHT, BODY FAT

A wrestling weight-certification program (WCP) is designed with the intention of minimizing unhealthy weight loss practices and increasing safe participation of student athletes in the sport (10,19). The National Federation of State High School Associations (NFHS) has made a recent rule that all state high school athletic associations have a wrestling WCP in place by the 2006/2007 season. The National Collegiate Athletic Association (NCAA) implemented a mandatory wrestling WCP approximately 10 yr ago as a result of three collegiate wrestlers dying during a 5-wk period in the fall of 1997 from complications caused by rapid weight reduction (5,10). The NCAA's wrestling WCP appears to be effective in reducing unhealthy weight cutting behaviors and promoting competitive equity (21).

A wrestling WCP at either the high school or collegiate level consists of having a qualified individual conduct a weight assessment of its wrestlers during the beginning of

each wrestling season using body weight, body composition, and specific gravity of urine (U_{sg}). The wrestler's fat-free mass (FFM) plus 5% body fat (collegiate) and 7% body fat (high school) is calculated to establish a minimum wrestling weight. At the high school level, each state is responsible for determining appropriate methods for assessing body composition and hydration status. In 1989 the Wisconsin Interscholastic Athletic Association (WIAA) implemented the first wrestling WCP that has served as a model statewide program to minimize unhealthy weight management behaviors of high school-aged wrestlers (19).

With approximately 250,000 high school wrestlers within the United States (www.nfhs.org), there is a need for a valid yet practical method to assess FFM. Skinfolds (SK) accurately assess body composition of high school wrestlers (19,23), but this method imposes some limitations. These include having access to enough trained assessors within a defined geographical region, technical error that may be present because of caliper performance, within- and between-tester differences in SK compressibility, and the inability to palpate the fat-muscle interface (12,15,16). Variations in SK compression have been attributed to such factors as subcutaneous fat thickness, state of hydration, and the distribution of fibrous tissue and blood vessels (12).

Recently, questions have arisen about body composition techniques other than SK in a wrestling WCP such as bioelectrical impedance analysis (BIA), air-displacement plethysmography (ADP), near-infrared (NIR) light interaction, and ultrasonography (ULTRA) (1,6,12,17,18,22,

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Submitted for publication August 2007.

Accepted for publication December 2007.

0195-9131/08/4005-0943/0

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DOI: 10.1249/MSS.0b013e318163f29e

24–27). ULTRA has been proposed as an alternative non-invasive technique to measure body density and subcutaneous fat thickness (1,12,22,24). ULTRA scanners are capable of measuring subcutaneous fat at depths of 100 mm or more and can reliably detect density interfaces with an accuracy of 1 mm (12). Stolk et al. (22) found a strong correlation ($r = 0.81$) between ULTRA and computed tomography (CT) for measurement of intraabdominal adipose tissue in overweight patients. In a study of 124 white men, aged 18–30 yr, Fanelli et al. (12) reported significant correlations ($r = -0.58$ to -0.70) between body density (D_b) determined by hydrostatic weighing and subcutaneous fat thickness using ULTRA at various anatomical locations.

To our knowledge, no studies have investigated the validity of ULTRA to estimate body composition in a wrestling population. Therefore, the purpose of this study was to evaluate the accuracy of ULTRA for measuring FFM when compared with hydrostatic weighing (HW) in a high school wrestling population. HW was chosen as the criterion method. SK were also included for comparative purposes because SK are commonly used to assess body composition in high school wrestlers (8,19). We hypothesized that there would be no significant differences between ULTRA or SK and HW for the estimation of FFM.

METHODS

Subjects. Subjects were male interscholastic wrestlers from local high schools ($N = 70$), who ranged in age from 14 to 18 yr, height (1.30–1.84 m), and weight (46.27–105.82 kg). Subjects were representative of all the high school weight categories (46.7–97.5 kg), with the exception of heavyweight. The heavyweight wrestlers were excluded because they typically do not have weight loss concerns. Subjects and parents gave written and informed consent, and the experimental procedures were approved by the institutional review board for investigations at Appalachian State University (ASU) and were in compliance with the American College of Sports Medicine policies for use of human subjects.

Testing schedule. All body composition testing occurred in the human performance laboratory at ASU ($N = 70$). All measurements were made in the preseason (September) and during the morning hours of Saturday. Height was determined using a stadiometer, and body mass was determined using a calibrated digital scale. All body composition measurements were made in a hydrated state. Baseline hydration was established by obtaining a urine specimen to measure U_{sg} , using a handheld optical refractometer (Atago, National Microscope Exchange, Redmond, WA). All subjects were considered to be adequately hydrated based upon their ability to produce a U_{sg} less than or equal to $1.025 \text{ g}\cdot\text{mL}^{-1}$ (3). During each testing session, the subject's body composition was evaluated by three different methods in the following order: 1) SK analysis, 2)

ULTRA thickness measurement, and 3) HW. The total time to assess body composition by the three different methods at each testing session was approximately 45 min.

SK testing. SK measures were recorded with Lange SK calipers at three sites: triceps, subscapular, and abdomen. The SK calipers were calibrated to $10 \text{ g}\cdot\text{mm}^{-2}$ by the manufacturer. SK were measured three times at each site to the nearest 0.5 mm, with the mean value recorded. All SK measurements were taken on the right side of the body. The tricep SK was measured vertically in the midline of the posterior aspect of the upper arm, midway between the lateral acromion process of the scapula and the inferior margin of the olecranon process of the ulna. The subscapular SK was measured as a diagonal fold just below the inferior angle of the scapular toward the right side of the body. The abdomen SK was raised vertically on the right side of abdomen 3 cm from the midpoint of the umbilicus. There was only one SK assessor, who is highly trained and experienced in measuring SK of wrestlers with a consistent test–retest reliability of $r > 0.90$. D_b was determined from the three SK measures using the prediction equation $D_b = [1.0982 - (\text{sum SK}) \times 0.000815] + [(\text{sum SK})^2 \times 0.0000084]$ validated by Lohman (14). %BF was determined from D_b using the Brozek equation (4). This %BF equation was also used with the D_b determined from HW and ULTRA.

HW. D_b was also determined by HW. HW was performed in a custom built, stainless steel tank, with three load cells interfaced to a computer (Exertech Fitness Equipment, Dresbach, MN). During HW, the subject was asked to expel as much air as possible from his lungs during complete submersion. After 5–10 trials, the highest underwater weight that could be repeated within 100 g by the subject was averaged and recorded. After completion of the HW trials, residual volume (RV) was measured (outside of the tank) by the oxygen dilution method using procedures described by Wilmore et al. (28). A minimum of two trials were completed, with the two closest readings within 10% being averaged to calculate RV.

ULTRA thickness measurements. ULTRA thickness measurements were made using the IntelaMetrix BX-2000 (IntelaMetrix Inc., Livermore, CA). The BX-2000 is an A-mode ULTRA device that uses a 2.5-MHz transmitter and separate receiver to measure tissue thickness. By using two separate ULTRA elements (transmitter and receiver), the background noise is significantly reduced, and thin tissue layers can be measured without the need for separate ULTRA coupling pads. Using planar angled transducer elements produces a region of overlap that reduces the sensitivity to interface angle.

Measurements using the BX-2000 were made by applying a thin layer of water-soluble gel to the contact surface on the device and then applying the device to the tissue. The transducer was applied manually, and care was taken to avoid compression of the subcutaneous fat. To assure accurate depth readings, the transducer was positioned until

the ULTRA beam was perpendicular to the tissue interfaces at each site. An angle of incidence other than 90° may result in a transmission parallax error (11). During the measurement, the BX-2000 is slid back and forth along the skin surface (approximately ± 5 mm from the measurement site) to provide local averaging of the measured signal. This technique significantly reduces the fine structure detail in the ULTRA signal and simplifies analysis. In the measured ULTRA signal, the first strong reflection occurs at the fat–muscle interface, which can be easily identified. D_b was then calculated using the prediction equations supplied by the manufacturer; these use thickness measurements made at the three anatomic sites: triceps, subscapular, and abdomen.

Statistical analysis. Multiple paired sample *t*-tests with Bonferroni's adjustment ($P < 0.025$) were performed to examine body composition differences. Values are expressed as means ± SD. To assess the agreement in FFM measured by ULTRA versus HW, linear regression analyses were performed with FFM by HW as the dependent variable. In the Bland–Altman plots, bias was calculated as the mean difference between methods, and the 95% limits of agreement were calculated as the bias ± 2SD of the differences between methods (1).

The standard error of the estimate (SEE) obtained from the linear regression model, and the prediction error (PE) representing the average deviation of individual variables from the line of identity ($y = x$), were also used to compare FFM measurements by ULTRA and HW (13). Pearson product–moment correlations between ULTRA and SK measures at each site were also calculated. For all tests, statistical significance was accepted at $P < 0.05$.

RESULTS

The characteristics of the study subjects are presented in Table 1. The sample consisted of 70 high school wrestlers who were moderately experienced, with an average 3.64 yr of wrestling experience. The subjects represented three different high schools in western North Carolina.

Table 2 presents the FFM data (means ± SD) and the relation between ULTRA and SK to HW for the sample. There was a strong correlation ($r = 0.97$) and no significant differences in mean FFM predicted by ULTRA (57.2 ± 9.7) and the criterion HW (57.0 ± 9.8). A significant underestimation ($P < 0.001$) was found for FFM predicted by SK

TABLE 2. Comparison of fat-free mass (FFM) between ultrasound (ULTRA) and skinfolds (SK) with hydrostatic weighing ($N = 70$).

Method	FFM (kg)	<i>R</i>	MD (kg)	SEE (kg)	PE (kg)
HW	57.0 ± 9.8				
SK	54.9 ± 8.8*	0.96	-2.1 ± 2.7	2.74	3.43
ULTRA	57.2 ± 9.7	0.97	0.2 ± 2.3	2.40	2.31

Values are expressed as means ± SD, FFM, bivariate correlation (*R*), mean difference (MD), standard error of estimate (SEE), and prediction error (PE).

* Significantly different ($P < 0.001$) vs hydrostatic weighing.

(54.8 ± 8.8) compared with HW, despite a strong correlation ($r = 0.96$).

Figures 1 and 2 illustrate the regression analysis when HW is the dependent variable (*y*-axis) and the prediction method is the independent variable (*x*-axis). Normal distribution of the data was confirmed by evaluating the skewedness and kurtosis. The regression equation (Fig. 1) for ULTRA resulted in a good standard error of estimate (SEE), a high adjusted R^2 , and a nonsignificant mean difference (mean ± SD) in estimating FFM (ULTRA – HW = 0.2 ± 2.3 kg). However, for SK (Fig. 2), the SEE was higher, and a mean difference ($P < 0.001$) was found in the estimation of FFM (SK – HW = -2.1 ± 2.7 kg). Significant correlations ($P < 0.001$) were also found for the ULTRA and SK measures at each site: triceps ($r = 0.91$), subscapular ($r = 0.76$), and abdomen ($r = 0.81$).

To evaluate systematic bias, Figures 3 and 4 illustrate the Bland–Altman plot of the difference between FFM measured by ULTRA or SK and HW versus the average FFM by the two methods. The regression lines revealed a nonsignificant correlation for ULTRA ($r = -0.07$),

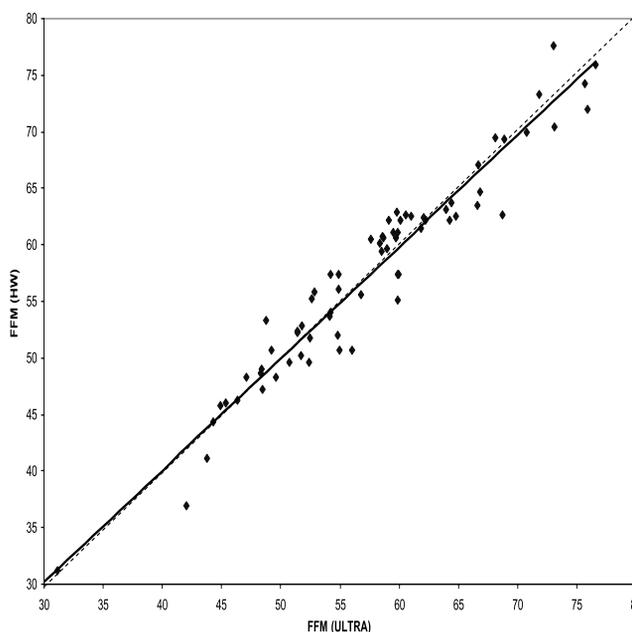


FIGURE 1—Comparison of fat-free mass (FFM) determined by hydrostatic weighing (HW) and ultrasound (ULTRA) in high school wrestlers. Linear regression ($y = 0.9875x + 0.57$, adjusted $R^2 = 0.94$, SEE = 2.40 kg, $P < 0.001$). Solid line indicates line of best fit. Dashed line indicates line of identity.

TABLE 1. Subject characteristics ($N = 70$).

Characteristics	Mean ± SD
Age (yr)	15.5 ± 1.5
Height (m)	1.6 ± 0.08
Weight (kg)	65.8 ± 12.7
Wrestling experience (yr)	3.6 ± 2.6
Urine specific gravity	1.02 ± 0.02
Residual lung volume (L)	1.50 ± 0.3
% Fat (HW)	12.8 ± 5.6

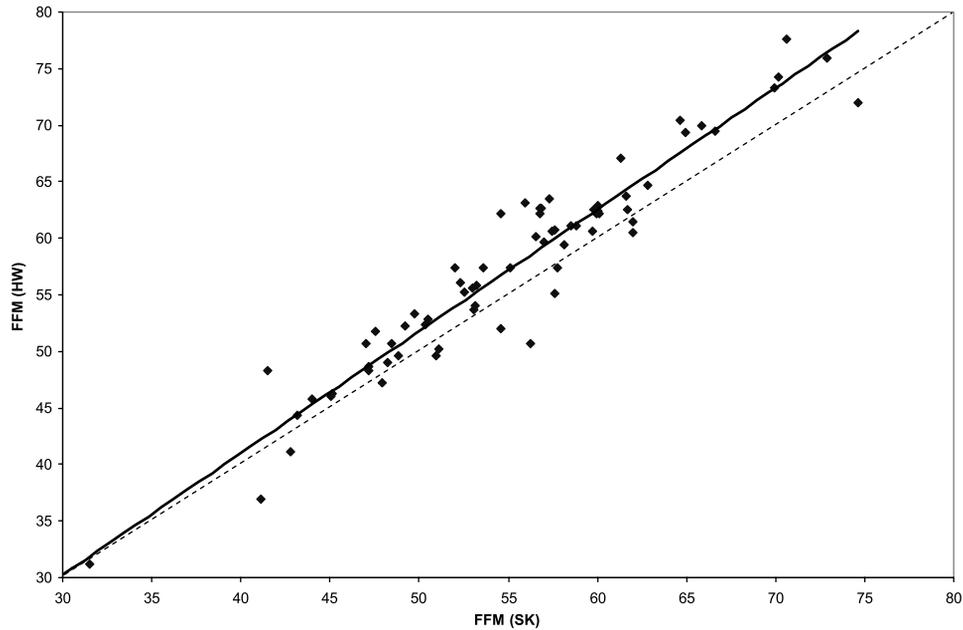


FIGURE 2—Comparison of fat-free mass (FFM) determined by hydrostatic weighing (HW) and skinfold analysis (SK) in high school wrestlers. Linear regression ($y = 1.0762x - 2.02$, adjusted $R^2 = 0.93$, SEE = 2.74 kg, $P < 0.001$). *Solid line* indicates line of best fit. *Dashed line* indicates line of identity.

and a significant negative correlation for SK ($r = -0.38$, $P = 0.001$).

DISCUSSION

Results from this investigation demonstrated that the ULTRA (IntelaMetrix BX-2000) system estimates FFM within an acceptable range when compared with HW in

high school wrestlers. There were no significant differences in mean FFM predicted by ULTRA and the criterion HW. The SEE and PE values of FFM were in the “excellent” range (2.0–2.5 kg) (13). When examining systematic bias of ULTRA using the Bland–Altman plot, no significant correlation was found between the difference of FFM measured by ULTRA and HW versus the average FFM by the two methods. Furthermore, these results indicate no

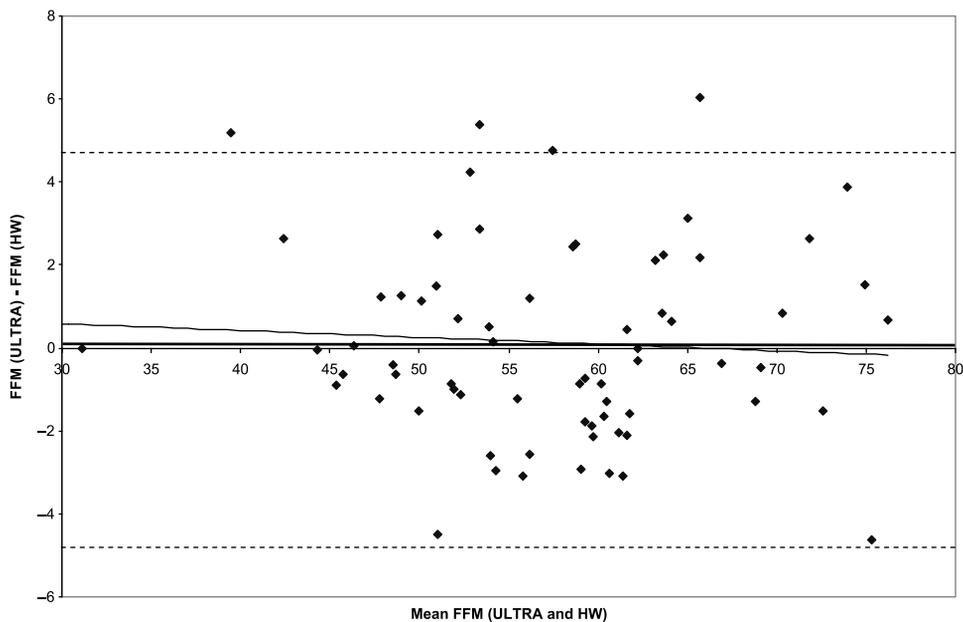


FIGURE 3—Bland–Altman plot of the difference between FFM measured by HW and ULTRA. The *light solid line* indicates line of best fit, the *heavy solid line* indicates the mean difference, and the *dotted lines* (mean difference \pm 2SD) indicate upper and lower 95% limits of agreement.

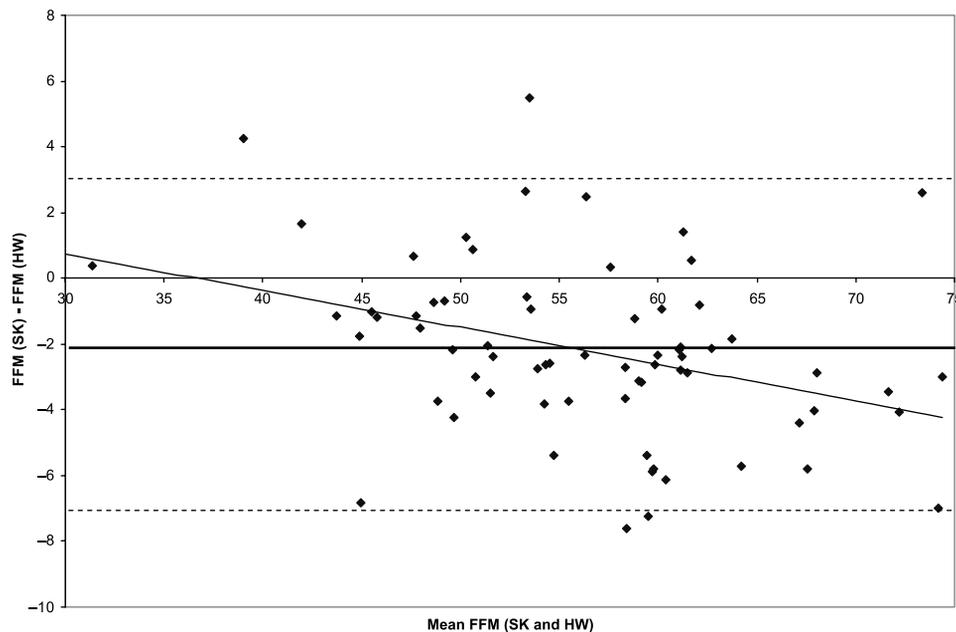


FIGURE 4—Bland–Altman plot of the difference between FFM measured by HW and SK. The *light solid line* indicates line of best fit, the *heavy solid line* indicates the mean difference, and the *dotted lines* (mean difference \pm 2SD) indicate upper and lower 95% limits of agreement.

systematic under- or overestimation of FFM despite a wide range of body weight in high school wrestlers (Fig. 3). Interestingly, a significant underestimation of FFM and overestimation of %BF was found for SK compared with HW.

To our knowledge, this is the first investigation to compare estimations of FFM from the ULTRA system (IntelaMetrix BX-2000) to HW in a heterogeneous high school-aged wrestling population. The size of the sample studied and its physical characteristics make it a representative sample of high school wrestlers (19,26). Therefore, results from the present investigation may be important with regard to wrestling WCP established by state high school athletic associations. The SEE value for ULTRA (2.31 kg) is comparable with other field-based measures of body composition in wrestlers: 1.72–1.97 kg for SK (6,26) and lower than leg-to-leg bioelectrical impedance (BIA) (3.5 kg) (7,26). In practical terms, the results of this study demonstrated that ULTRA predicted FFM within 2.31 kg (5.0 lb) 68% of the time and within 7.3 kg (16.0 lb) 95% of the time in this sample. This compares well with another field-based measure like leg-to-leg BIA, which predicts FFM within 3.64 kg (8.0 lb) 68% of the time and within 7.3 kg (16.0 lb) 95% of the time in a sample of 129 high school wrestlers (26). While HW, ADP, and dual x-ray absorptiometry (DXA) have been considered the “gold standard” for minimal wrestling weight assessment, these are clearly not practical for use when testing wrestlers on a mass basis. Therefore, careful determination of a field-based method to assess body composition becomes an important objective of the health care provider. When state high school athletic associations determine which body

composition method(s) to employ when implementing a wrestling WCP, the following factors should be evaluated: 1) accuracy and precision (validity), 2) cost, 3) competitive equity, 4) practicality (i.e., DXA and HW are not very practical), 5) ease of use and administration, and 6) safety.

The results of the present investigation are consistent with previous research evaluating the accuracy of ULTRA in other populations. Fanelli et al. (12) reported significant correlations ($r = 0.58$ – 0.70) between body density (D_b) determined by HW and subcutaneous fat thickness using ULTRA at seven different anatomic locations in 124 white men, ages 18–30 yr. Stolk et al. (22) found in 19 overweight patients that ULTRA was a reliable and reproducible method to assess the amount of intraabdominal adipose tissue compared with both CT and MRI, with correlations ranging from $r = 0.55$ to 0.84 . In a study of 13 healthy, active (regular exercise habits: aerobic exercise 2 – $3 \times \text{wk}^{-1}$, ~ 60 min) women ages 19–25 yr, Abe et al. (1) found highly significant correlations ($r = 0.79$ – 0.95) for subcutaneous adipose tissue between MRI and ULTRA. Considering that all previous research with ULTRA has been completed on nonathletic samples, future validation research is clearly warranted in other wrestling populations (i.e., collegiate or international) and/or other sport populations in which body composition assessment is deemed important. In addition, future research should also consider both within- and between-tester reliability of ULTRA when assessing body composition over time.

An interesting yet unexpected secondary finding of the present investigation was a significant underestimation of FFM (54.9 ± 8.8 kg) and overestimation of %BF ($15.8 \pm$

6.2) found for SK compared with HW in this high school wrestling sample. From our review of the literature, this is the first data set to demonstrate when using SK an underestimation of FFM and overestimation %BF when employing the Lohman (14) equation for the estimation of D_b and the Brozek equation (4) for %BF in a wrestling sample. This finding is in direct contrast to the many previous investigations that have shown its validity in estimating body composition in wrestlers (6,7,9,20,23–26). In a previous investigation with 129 high school wrestlers, Utter et al. (BIA) reported no significant differences in estimated FFM between SK (56.1 ± 8.9 kg) and HW (56.2 ± 9.9 kg). However, in that study, a significant systematic bias was found for both SK and BIA when evaluating the difference between FFM measured by BIA or SK and HW versus the average FFM by the two methods. The regression lines indicated significant negative correlations for both SK ($r = -0.44$, $P < 0.001$) and BIA ($r = -0.39$, $P < 0.001$). This same systematic bias was found in the present study with SK ($r = -0.38$, $P = 0.001$); however, it was not found for ULTRA ($r = -0.07$). The reason for the overestimation %BF in the present study is unknown and should be evaluated within the context of the previous research, which has demonstrated validity of SK in estimating the body composition of wrestlers (6,7,9,20,23–26). However, the systematic bias found for SK in the present study and a previous investigation (26) suggests that “bias” should be included and evaluated as an outcome variable in future

validation studies concerning body composition assessment techniques in wrestlers.

This study demonstrated that FFM values measured by the ULTRA (IntelaMetrix BX-2000) system were not statistically different when compared with values obtained by HW in a heterogeneous high school wrestling population during a hydrated state, and, therefore, this method should be considered as an alternative to SK and BIA methods for determining the minimum weight for wrestlers. Considering that any field-based method to assess body composition may introduce biological and technical error that will affect the precision of FFM estimation at the individual level, professional judgment and careful interpretation of results (including an option for an appeal process) should be employed for the purpose of establishing a minimum wrestling weight. ULTRA has several advantages: it does not require a high degree of technician skill and, therefore, is easy to use; it is safe; results are instantaneous; and the device is portable. These advantages may make ULTA attractive to educational institutions that may not have access to trained SK assessors, HW, ADP, and to address concerns that have been expressed by coaches, officials, and athletic trainers who question the results of SK testing performed by someone who may not be completely objective or impartial.

This work was funded by IntelaMetrix Inc., Livermore, CA. The results of the present study do not constitute endorsement of any product by the authors or Appalachian State University.

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