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Validity of Self-Assessment Techniques for Estimating Percent Fat in Men and Women

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ABSTRACT

This study examined the validity of the Accu-Measure™ (AM) and the Futrex 1000 (F-1000) for estimating % body fat (BF) by comparing the estimates to values obtained from skinfold equations (Sum3). Thirty Caucasian men (age 23 ± 3 yrs) and 26 Caucasian women (21 ± 2 yrs) participated in the study. Subjects practiced, then determined their %BF using the AM and the F-1000, while skinfold sites from the Sum3 equations (men = abdomen, chest, thigh; women = triceps, suprailiac, thigh) were measured by an experienced investigator with a Lange caliper. The validity (vs. underwater weighing) for each procedure was determined by examining the constant error (*CE*), standard error of the estimate, *r*, and total error (*TE*). The results were similar for both genders and indicated that the AM, which resulted in the lowest *TE* values and nonsignificant ($p > 0.02$) *CE* values, was as accurate as the Sum3 equations for estimating %BF, and is recommended over the F-1000 for self-assessments of body composition.

Key Words: body composition, Accu-Measure, skinfold, near-infrared interactance, underwater weighing

Introduction

The ability to accurately assess percent body fat (%BF) has important implications for both health and athletic performance. Excess body fat has been associated with chronic diseases including coronary heart disease, hypertension, high cholesterol, and some cancers (8). In addition, competitive and recreational athletes are interested in monitoring their body composition since body fat beyond what is needed for optimal functioning may impair performance, particularly in activities that require running or jumping (23).

Body composition testing is commonly done at fitness clubs, clinics, and other health care or recreational facilities by trained personnel, often at a substantial cost. Furthermore, in many settings, privacy is limited and measurements may be taken at inconvenient times under less than ideal conditions. Thus there is a need for a cost-effective self-assessment technique that accurately predicts %BF and requires little skill to administer.

Recently, two new body composition devices have come on the market: the Futrex 1000 (F-1000), a near-infrared device (NIR), and the Accu-Measure™ (AM) skinfold caliper. Each costs less than $100 and the manufacturers claim they are as accurate as more sophisticated body composition techniques which require special equipment, time, and trained personnel to administer. If valid, these techniques would be attractive alternatives for persons wishing to assess their body composition without the inconvenience, expense, and lack of privacy of conventional body fat testing at a health club. Thus the purpose of this study was to compare the validity of %BF estimates from the F-1000 and AM with those obtained from skinfold equations.

Methods

Thirty Caucasian men (age 23 ± 3 yrs; range = 19–33 yrs) and 26 Caucasian women (age 21 ± 2 yrs; range = 18–29 yrs) recruited from a university population volunteered to participate in the study. The purpose of the study and a description of the testing protocol was explained to each subject, and written informed consent was obtained prior to inclusion in the study.

Body density (D_b) was assessed from underwater weighing (UWW) with correction for residual volume (RV) using the oxygen dilution method of Wilmore (22). Residual volume was determined on land with the subject seated as in UWW. The average of similar scores (within 0.1 L) from 2 to 3 trials was used as the representative RV.

Underwater weight was measured in a submersion tank in which a metal swing seat was suspended from a Chatillon 9-kg scale. The average of the 2 to 3 highest weighings from 6 to 10 trials was used as the representative underwater weight. Percent body fat was calculated from D_b using the revised formula of Brozek et al. (2).

Previous test-retest reliability data for UWW from our laboratory indicated that for young men ($n = 16$) measured 24–72 hrs apart, the intraclass correlation (*R*) was 0.98 with a standard error of estimate (*SEE*) of 0.9% BF. These values are comparable to those reported by Thomas and

Cook (20) and Jackson et al. (12). Furthermore, the UWW procedures we used were standardized as part of an inter-university study (21) and found to be highly consistent with those from 3 other laboratories.

Skinfold measurements were taken on the right side of the body with a Lange caliper by an investigator who had previously demonstrated a test-retest reliability of $R > 0.90$. Measurements were taken according to the recommendations of Jackson and Pollock (11) at the abdomen, chest, and thigh for the men, and at the triceps, suprailiac, and thigh for the women. Body density values were calculated using the generalized sum-of-3 (Sum3) skinfold equation of Jackson and Pollock (10) for the men, and Jackson, Pollock, and Ward (13) for the women, and were then converted to %BF using the revised formula of Brozek et al. (2) (Table 1).

Each subject did a self-assessment with the AM skinfold caliper using the protocol described by the manufacturer (Accu-Measure, Parker, CO). Following a detailed explanation of the procedure, subjects practiced and then measured the suprailiac skinfold on the right side of their body. Using the left thumb and forefinger, they grasped the skinfold 1 inch above the iliac crest and placed the jaws of the instrument over the midpoint of the skinfold using the right hand. They then pressed with the right thumb until they felt a slight click when the slide member automatically stopped at the appropriate reading. The measurement was recorded to the nearest millimeter and the slide member was returned to the starting position. The procedure was repeated 3 times and the average of the 3 readings was used as the representative value, as recommended by the manufacturer. The subject's age and skinfold measurements were used to determine %BF using nomograms provided by the manufacturer.

Each subject obtained %BF estimated from NIR using the F-1000 according to the procedures recommended by the manufacturer (Futrex, Gaithersburg, MD). This device emits infrared light of specific wavelengths (940 and 950 nm) into the anterior midline of the biceps brachii midway between the antecubital fossa and the acromion process of the dominant arm (as determined by throwing preference). A silicon based detector then measures the intensity of the re-emitted light which is expressed as optical density (OD). Percent BF was estimated using a preprogrammed generalized multiple regression equation that includes height, weight, and OD values. The specific equation, however, was not available from the manufacturer. The instrument was calibrated prior to each measurement with the manufacturer-supplied optical standard.

All body composition determinations were performed on the same day following a 12-hr fast (ad libitum water intake was allowed). The subjects were also instructed to avoid exercise for at least 12 hrs prior to testing. No information on the timing of the women's menstrual cycles was available.

Validity of %BF estimates (Sum3, AM, F-1000) was based on an evaluation of predicted values vs. the criterion value from UWW by calculating the constant error (*CE* = estimated %BF – actual %BF), *r* value, *SEE* ($SEE = SD\sqrt{1 - r^2}$), total error ($TE = \sqrt{\Sigma[\text{predicted} - \text{actual}]^2/\text{n}}$), and the similarity between the standard deviations of predicted and actual values.

Results

The subjects' descriptive characteristics are presented in Table 1. Mean %BF determined by UWW was 13.4 ± 5.8% (range 6.6–29.5%) for men and 17.6 ± 5.8% (range 8.1–30.6%) for women. Figures 1 and 2 show the relationships between predicted and UWW %BF values for the Sum3, F-1000, and AM for the men and women, respectively. Table 2 presents the results of the validation analyses. The statistical significance of the *CE* values for each equation was determined using dependent *t*-tests, and the Bonferroni correction (14) was used to adjust the significance for each comparison. The *CE* values ranged from –2.2% BF (Sum3) to 5.0% BF (F-1000) for the men, and from –1.5% BF (Sum3) to 4.4% BF (F-1000) for the women. The *CE* values associated with the AM for both the men (–1.1% BF) and the women (1.0% BF) were nonsignificant at the adjusted family-wise alpha ($p > 0.02$).

The validity coefficients ranged from 0.52 (F-1000) to 0.88 (Sum3) for the men, and 0.62 (F-1000) to 0.82 (AM) for the women. Significant ($p < 0.05$) test-retest intraclass correlation coefficients were found for repeated determinations of %BF from the self-assessment

Table 1
Descriptive Characteristics

Variable	*M*	±*SD*	Range
Men (n = 30)			
Age	23	3	19–33
Height (cm)	180.1	6.3	167.5–191.5
Weight (kg)	80.0	12.0	61.9–104.8
% Fat			
UWW	13.4	5.8	6.6–29.5
Sum3	11.2	5.8	3.5–27.6
F-1000	18.4	5.7	8.3–30.3
AM	12.3	4.4	4.9–25.8
Women (n = 26)			
Age	21	2	18–29
Height (cm)	165.7	7.5	151.4–186.4
Weight (kg)	59.8	9.7	50.8–97.0
% Fat			
UWW	17.6	5.8	8.1–30.6
Sum3	16.1	4.2	9.8–25.6
F-1000	22.0	4.4	13.1–29.6
AM	18.6	3.8	11.3–27.0

Sum3 Males: % Fat = {4.57 / [1.10938–0.0008267 (sum of chest, abdominal, & thigh skinfolds) + 0.0000016 (sum of chest, abdominal, & thigh skinfolds)^2 – 0.0002574 (Age)] – 4.142} × 100.

Sum3 Females: % Fat = {4.57 / [1.0994921 – 0.0009929 (sum of triceps, thigh, & suprailiac skinfolds) + 0.0000023 (sum of triceps, thigh, & suprailiac skinfolds)^2 – 0.0001392 (Age)] – 4.142} × 100.

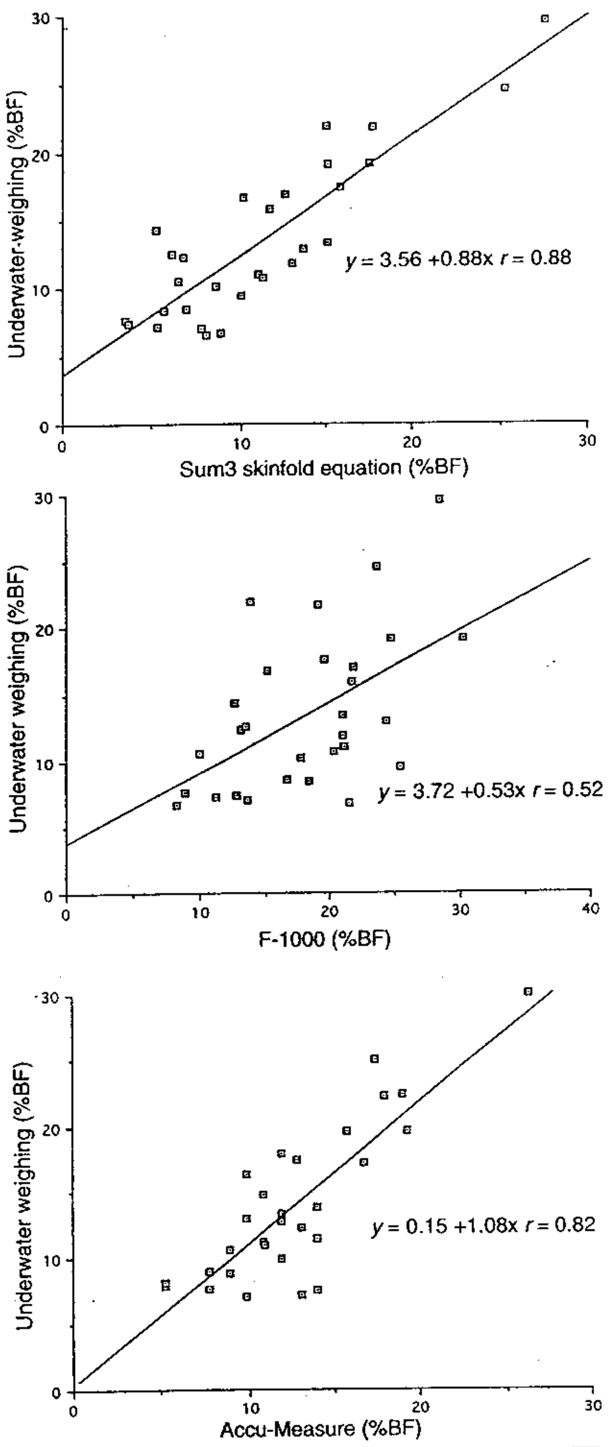

Figure 1. Relationships between skinfold (Sum3), F-1000, and Accu-Measure predicted %BF values and the values from underwater weighing for the men.

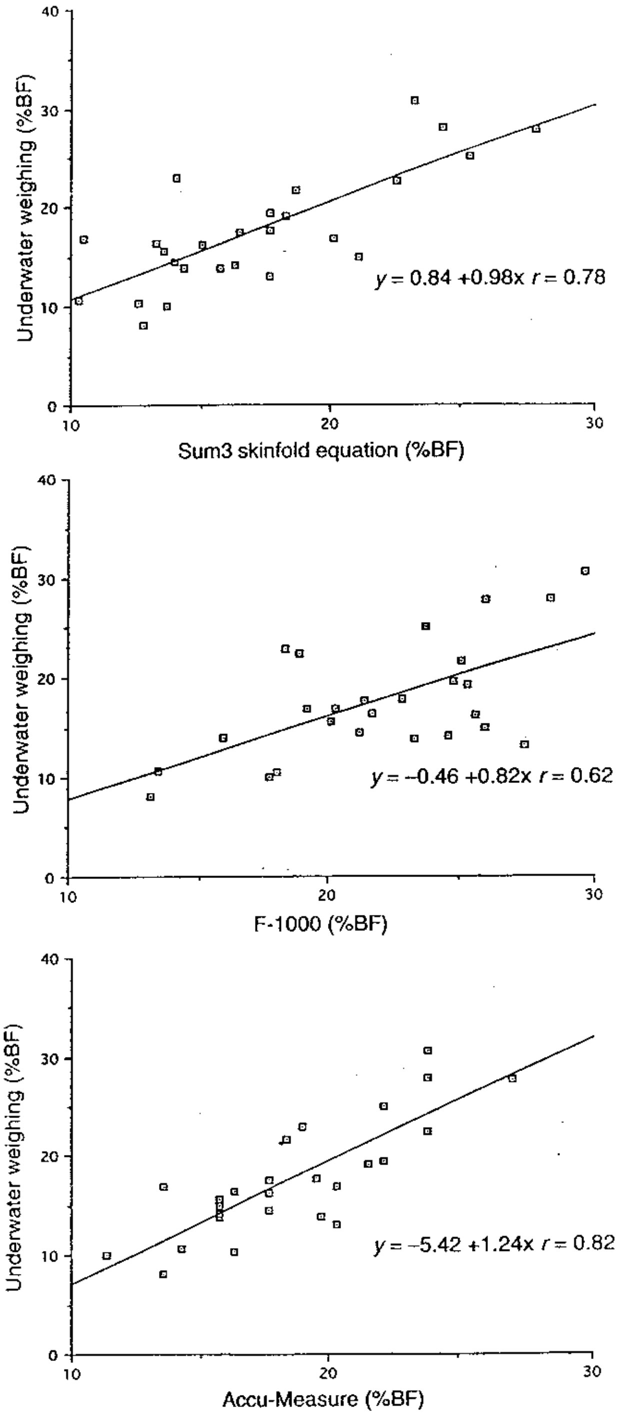

Figure 2. Relationships between skinfold (Sum3), F-1000, and Accu-Measure predicted %BF values and the values from underwater weighing for the women.

techniques. The *R* values for the men were 0.86 (*SEE* = 2.3% BF) for the AM, and 0.97 (*SEE* = 1.4% BF) for the F-1000, while the reliability coefficients for the women resulted in identical values of 0.95 (AM *SEE* = 1.2% BF; F-1000 *SEE* = 1.4% BF).

The *SEE* values ranged from 2.9% BF (Sum3) to 5.1% BF (F-1000) for the men, and from 3.4% BF (AM) to 4.6% BF (F-1000) for the women. However, *TE*, which accounts for errors associated with both the *CE* and *SEE* (17), ranged from 3.5% BF (AM) to 7.4% BF (F-1000) for the men, and 3.6% BF (AM) to 6.3% BF (F-1000) for the women. The *SD* values associated with the Sum3 and F-1000 for the men (5.8 and 5.7% BF, respectively), were similar to the distribution from UWW (5.8% BF), while the AM (*SD* = 4.4% BF) condensed the distribution (Table 1). The *SD* values associated with all 3 techniques for the women (Table 1) resulted in substantially condensed distributions (3.8 to 4.4% BF) when compared to UWW (5.8% BF).

Discussion

The results of the analyses were evaluated based on the recommendations of Lohman (15) and included the following: (a) the mean values for actual and predicted %BF should be comparable; (b) a low *SEE* value is desirable and preferred over the correlation coefficient, since the correlation is likely to be affected by intersample variability in %BF; (c) *TE* should be calculated because it reflects the true differences between actual and predicted %BF values, whereas *SEE* only reflects error associated with the regression between variables; and (d) the *SD* values for the actual and predicted %BF values should be in close agreement. Although all these criteria deserve attention, *TE* is the best single criterion for determining the difference between actual and predicted %BF values (17).

The results of the validation analyses were similar for men and women and indicated that the AM, which resulted in *TE* values of 3.5% BF and 3.6% BF, respectively, was as accurate as the Sum3 equations (*TE* = 3.7% and 3.8% BF, respectively) for estimating %BF. Furthermore, the *CE* values associated with AM for both men (–1.1% BF) and women (1.0% BF) were not significant at the adjusted family-wise alpha ($p > 0.02$).

To our knowledge, no previous studies have examined the validity of AM for estimating %BF in men or women. However, the results for the Sum3 equation are similar to the findings of several validity studies (Table 3). The *r*, *SEE*, and *TE* values reported for the men in the present study are comparable to those reported by Clark et al. (3), Houmard et al. (6), Israel et al. (9), and Stout et al. (18). The *TE* value found in the present study for the women is similar to the value reported in the original derivation study by Jackson et al. (13) (*TE* = 3.7% BF) for the cross-validation sample. In contrast, Stout et al. (19) reported a considerably smaller *TE* value of 2.4% BF in 41 nonathletic women who were similar in age and body composition to the present sample of women (20.1 yrs and 18.9% BF) (Table 3).

Few studies have examined the validity of the F-1000 for predicting body composition characteristics in men and women (1, 7, 18, 19). In the present study, the F-1000 significantly ($p < 0.02$) overestimated %BF in both men and women and resulted in *SEE* and *TE* values too large to be of practical use (*TE* = 7.4% BF and 6.3% BF, respectively). The *SEE* value for the men (5.1% BF) is similar to values reported by Housh et al. (7) and Stout et al. (19) (Table 3). The *TE* value reported by Stout et al. (18), however, was somewhat lower than that in the present study, whereas the *TE* value reported by Housh et al. (7) for 58 youth wrestlers was markedly higher.

Brown et al. (1) examined the validity of NIR for estimating body composition and reported that the F-1000 (*SEE* = 4.0% BF) was as accurate as skinfolds (*SEE* = 4.0% BF) for estimating % BF in 27 women. In addition, Stout et al. (19) reported *SEE* and *TE* values of 4.1 and 5.0% BF, respectively, in a study examining the va-

Table 2
Validity of % Fat Values Estimated From Skinfold and F-1000 Equations

Comparison	*CE*	*r*	Intercept	Slope	*SEE*	*TE*
Men						
Sum3 vs. UWW	–2.2*	0.88	3.56	0.88	2.9	3.7
F-1000 vs. UWW	5.0*	0.52	3.72	0.53	5.1	7.4
AM vs. UWW	–1.1	0.82	0.15	1.08	3.4	3.5
Women						
Sum3 vs. UWW	–1.5*	0.78	0.84	0.98	3.6	3.8
F-1000 vs. UWW	4.4*	0.62	–0.46	0.82	4.6	6.3
AM vs. UWW	1.0	0.82	–5.42	1.24	3.4	3.6

*$p < 0.02$; alpha adjusted by Bonferroni (14).

Table 3
Validity of Both Equations in Selected Reference Groups

Source	*N*	Age (yrs)	Actual % BF	*CE*	*r*	*SEE*	*TE*
Sum3 equ.							
Males							
Present study	30	23 ±3	13.4 ±5.8	–2.2	0.87	2.9	3.7
Clark et al. (3)	35	39.1 ±14.0	17.4 ±7.4	–3.0	0.92	2.8	4.1
Houmard et al. (6)	39	19.8 0.1[†]	15.1 1.1[†]	–1.4	0.89	3.06	n/a
Israel et al. (9)	80	25.8 1.14[†]	12.9 0.37[†]	–0.6	0.87	3.4	n/a
Jackson et al. (10)	95	33 ±11.5	18.7 ±8.3	–0.6	0.91	n/a	3.2
Stout et al. (18)	57	22 ±3	15.1 ±6.2	–2.5	0.90	2.7	3.6
Females							
Present study	26	21 ±2	17.6 ±5.8	–1.5	0.78	3.6	3.8
Heyward et al. (5)	77	36.3 ±11.7	23.6 ±4.5	–0.3	0.65	3.44	3.85
Jackson et al. (13)	82	29.9 ±11.2	24.8 ±6.4	0.3	0.82	3.3	3.7
Stout et al. (19)	41	20.1 ±2.3	18.9 ±4.4	1.2	0.88	2.1	2.4
F-1000 equ.							
Males							
Present study	30	23 ±3	13.4 ±5.8	5.0	0.52	5.1	7.4
Housh et al. (7)	58	11.4 ±1.5	10.7 ±5.1	–14.7	0.29	5.0	16.2
Stout et al. (18)	57	22 ±3	15.1 ±6.2	3.3	0.63	4.8	6.1
Females							
Present study	26	21 ±2	17.6 ±5.8	4.4	0.82	4.6	6.3
Brown et al. (1)	27	24 ±1[†]	37.2 ±1.2[†]	–2.7	0.78	4.0	n/a
Stout et al. (19)	41	20.1 ±2.3	18.9 ±4.4	1.8	0.37	4.1	5.0

[†] Values in Houmard et al. (6), Israel et al. (9), and Brown et al. (1) are *M* ± *SEM*. n/a = values not reported.

lidity of different methods for estimating % BF in 41 nonathletic women. As shown in Table 3, the *SEE* value associated with the F-1000 for the women in the present study (4.6% BF) is similar to those reported by Brown et al. (1) and Stout et al. (19); however, the *TE* value reported in the present study (6.3% BF) is considerably greater than that reported by Stout et al. (19).

Generally, for indirect methods of estimating body composition such as skinfolds, bioelectrical impedance, and NIR, the acceptable limit of accuracy is 3–4% BF (4, 15, 16). In the present study, the AM and Sum3 equations resulted in *TE* values ≤3.8% BF, and thus are recommended over the F-1000 for assessing body composition in college-age Caucasian men and women with lean to average body fatness. It should be noted, however, that the AM condensed the distribution when compared to UWW, which may result in errors at the extreme ends of the body composition distribution.

A salient feature of the AM is that it is an inexpensive self-assessment technique that requires little skill to administer, therefore offering an attractive alternative for individuals who wish to determine their body composition without the inconvenience, expense, and lack of privacy of conventional body fat testing at clinics or recreational facilities. Because age, gender, and ethnicity have all been found to affect fat distribution, thus yielding different relationships between a given set of skinfolds and total body fatness (16), future studies are warranted using the AM to confirm the present findings, with similar samples of men and women as well as athletes and groups differing in age and ethnicity.

Practical Applications

The present study is the first to report the magnitude of errors associated with AM for estimating %BF in college-age Caucasian men and women with lean to average body fatness. Based on the results of the validation analyses, the AM, a cost-effective self-assessment technique that requires little skill to administer, provided accurate measures of %BF and therefore is recommended over the F-1000 for estimating body composition in young Caucasian adults. In addition, since the AM is a self-assessment technique, it may offer an attractive alternative for those who wish to estimate their body composition without the inconvenience, expense, and lack of privacy of conventional body fat testing. Future research is warranted to replicate these findings and determine the utility of the AM for monitoring training-induced changes in body composition.

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