Original Research

The Validity Of 7-Site Skinfold Measurements Taken By Exercise Science Students

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ABSTRACT

International Journal of Exercise Science 6(1): 20-28, 2013. Skinfold (SKF) measurement is arguably the most ubiquitous method of estimating percent body fat (%BF) because of cost, ease, and feasibility. However, it is unknown how accurately novice exercise science students measure SKF thickness. Thus, the purpose of this study was to determine the validity with which exercise science students in an Exercise Physiology course measured skinfold thickness and estimated percent body fat (%BF) when compared to a skilled technician. Twenty-three novice undergraduate students were afforded both verbal measurement instruction and visual measurement demonstration and, subsequently, assessed SKF thicknesses of a male and female testee. %BF was calculated using measurements obtained by the skilled technician and students. Comparisons were made between measurements taken by the skilled technician and students using error, absolute error, and one sample *t*-tests. For the female testee, average error ranged from -0.5 mm to -4.8 mm for the 7-sites, 1.7±15.4 mm for the sum of 7-sites, and -3.7±2.6% for %BF. The average absolute error ranged from 1.2 mm to 4.9 mm for the 7-sites, 23.3±12.7 mm for the sum of 7-sites, and 3.9±2.2% for %BF. For the male testee, average error ranged from 0.0 mm to 0.9 mm for the 7-sites, 2.9±8.5 mm for the sum of 7-sites, and 0.5±1.4% for %BF. The average absolute error ranged from 0.6 mm to 1.1 mm for the 7-sites, 4.8±7.5 mm for the sum of 7-sites, and 0.8±1.2% for BF%. The one sample *t*-tests revealed no significant differences in the sum of 7-sites and %BF for the male model ($p>0.05$), but significant differences were found for the female model ($p<0.05$). From a practical perspective, when novice exercise science students were provided both verbal and visual instructions of SKF measurement technique, students were able to accurately assess %BF of a male testee as compared to the skilled technician. With respect to the female testee, however, students underestimated the sum of the 7 SKF sites by ~ 20 mm when compared to the skilled technician. Additional tutelage and practice may be necessary when teaching SKF measurement of females and/or individuals with higher %BF to novice undergraduate exercise science students.

KEY WORDS: Body composition, novice, validity, accuracy

INTRODUCTION

Body composition (BC) is an important component of health-related physical fitness. High levels of body fat (BF), specifically abdominal fat, can significantly increase risk for cardiovascular disease. The seven-site skinfold (SKF) measurement technique is arguably the most common method of BF estimation. This method is attractive because of its low relative cost when compared to reference methods such as hydrodensitometry, air displacement plethysmography, and dual-energy X-ray absorptiometry (8). SKF measurement is quick and less invasive compared to aforementioned reference methods which require minimal clothing, complete exhalation, and/or exposure to X-ray photon. Moreover, as a field measure, SKF technique is feasible, reliable, and valid (14).

Although BF is commonly quantified in health- and performance-based research, measurement issues related to BF assessment have been investigated for decades (3). The validity of SKF measurements can be affected by numerous variables. Measurement technique, technician experience, hydration, sex, age, and ethnicity are significant factors when measuring BC as demonstrated by the numerous population-specific equations used to calculate body density and BF (11). Consequently, measurement technique can be improved to reduce error. The National Strength and Conditioning Association (NSCA) and the American College of Sports Medicine (ACSM) have set specific guidelines for the SKF testing procedures including specific locations of measurement, number of times each site should be measured, the acceptable margin of error between measurements, etc. (1, 2) Heyward and Wagner (8) suggested that SKF technicians be meticulous in marking anatomical landmarks, take a minimum of two measurements, practice on over 50 clients, and be trained and mentored by skilled technicians to improve measurement skills.

Hume and Marfell-Jones (10) investigated the importance of adherence to protocols by examining the differences in SKF measurement with a small change in the SKF site measurement location. Using the International Standards for Anthropometric Assessment (12), two International Society for the Advancement of Kinanthropometry (ISAK)-accredited testers measured the eight defined ISAK sites. Along with each ISAK-defined site, eight peripheral sites 1 cm away from the defined sites were also measured (all sites, then, assumed a 3x3 grid with the ISAK-defined site located centrally in the grid). The results indicated that 70% of the peripheral site measurements were statistically different from the ISAK-defined site measurements and 39% were considered “non-trivial” (Effect Sizes > .2). Hume and Marfell-Jones (7) noted that these results reinforced the importance of strict adherence to a proper measurement protocol.

Previous research on SKF measurement has uncovered many factors of reliability and validity for this method of BF measurement (7, 10, 11, 15, 16). However, as validation is a continual process (18), other validity issues may still be elucidated. Accurate SKF measurement technique has been investigated in testers who were well-trained (10, 15), but the validity of SKF measurements taken by novices is uncertain. Because SKF measurement is relatively inexpensive and less invasive than other BF estimation methods (8, 15), it is commonly taught in universities to undergraduate students in kinesiology, physical education, athletic training, and Exercise Science courses. This skill of quantifying %BF via SKF measurement then is commonly used in fields such as personal training and strength and conditioning to monitor changes in BC. As with most human measurements, proper SKF measurement technique is a skill not quickly or easily acquired. A clearer understanding of the validity of novice SKF measurements would allow for proper feedback pertaining to the skill-acquirement process of this measurement technique for professors, practitioners, and students. Therefore, the purpose of this study was to determine the validity with which exercise science students in an Exercise Physiology course measured SKF thickness and estimated %BF when compared to a skilled technician.

METHODS

Participants

Participants were Exercise Science majors (*N* = 23) enrolled in an undergraduate exercise physiology laboratory class at a university in the southeast United States. They were considered novice SKF technicians as they possessed little to no knowledge of assessing BC via SKF technique. The conducted study met ethical standards (5) and all volunteers signed an informed consent form, approved by the University's Institutional Review Board for human subject use, prior to participation. Two participants, one female (age = 21 years) and one male (age = 23 years), were asked to serve as testees for the SKF measurements. Both study testees attended all three laboratory sessions to be measured by the novice exercise science students.

Protocol

A skilled technician (i.e., Ph.D., ACSM and NSCA certified) with over 20 years of experience measuring and teaching SKF procedures measured the SKFs of the male and female testees for the investigation. Once the SKF data were recorded for the testees, the novice exercise science students came into the laboratory to learn the SKF measurement technique. The skilled technician then spent the next 45 minutes describing the location of the seven sites verbally as well as visually locating the seven sites on both skeleton and human models in accordance with the guidelines set forth by ACSM (1). Once the locations of the SKF were explained, the skilled technician then demonstrated the technique to obtain a proper SKF pinch while stating:

"*Firmly but gently, pinch the skin and subcutaneous fat between the thumb, forefinger, and middle finger. Open the skinfold caliper and measure the skinfold approximately 1 cm below your fingers and approximately 1 cm deep into the skinfold. Do not release the skinfold while taking the measurement. Once you have obtained the skinfold measurement, release the caliper from the skinfold. Take a minimum of 2 measurements at each site. If the measures do not agree within 1 millimeter, subsequent assessments should be taken until all values are within 1 millimeter*."

Upon completion of instruction, the students exited the laboratory and waited in a hallway. Only two students were then allowed back into the laboratory to employ what they had learned via locating, measuring, and recording the SKF on the male and female testees using a Lange Skinfold Caliper (model 68092). Once all data had been collected, students exited the laboratory and two more students entered the laboratory. This process was repeated until all students completed the process of locating, measuring, and recording the SKF measurements on the testees. The above procedures were conducted three times as there were three separate laboratory sessions associated with the Exercise Physiology lecture course.

Statistical Analysis

Data analyses were performed using SPSS (version 19.0) and Microsoft Excel 2007. Data were analyzed separately for the male and females testees. Descriptive statistics were computed for all variables. First, the number of SKF measurements taken by the exercise science student at each site was computed. Error and absolute error were calculated between the SKF measurements taken by the skilled technician and the exercise science students. Percent BF was computed using the skilled technician's and students' measurements, and error and absolute error were calculated between those variables. One sample *t*-tests were used to compare the mean SKF thickness measured by the exercise science students and the skilled technician at each site for both testees. The Mauchly's sphericity test was conducted prior to further data analysis. Repeated measures ANOVAs were performed to assess mean difference in absolute error among different sites for the female and male testees' measurements and post hoc analyses were conducted when appropriate. The alpha level was set at 0.05 for ANOVAs testing and was adjusted using bonferoni transformation for the one sample t-tests and was set at 0.003.

RESULTS

The average number of measurements taken by the students for each SKF site can be found on Table 1. The students took between two to six measurements for the female testeee and two to four measurements for the male testee. SKFs for each site, sum of SKFs, %BF measured by the skilled technician and the average SKF for each site, sum of SKFs, and %BF measured by the students are found in Table 2. Sum of SKFs, and %BF measured by the skilled technician were 95 mm, 17.8%, and 37 mm, 3.8%, for the female and male testees, respectively. The average sum of SKFs and %BF measured by the students were 73±15 mm, 14.2±2.6%, and 40±8 mm, 4.2±1.3%, for the female and male testees, respectively. For the female participant, the average error ranged from -0.5 mm to -4.8 mm and the average absolute error ranged from 1.2 mm to 4.9 mm for the seven sites (see Table 3). For the male participant, the average error ranged from 0.0 mm to 0.9 mm and the average absolute error ranged from 0.5 mm to 1.1 mm for the seven sites (see Table 3).

Table 1. Number of measurements taken by students.

Site	Female	Male
Chest	2.3 ± 0.6	2.1 ± 0.3
Axilla	2.3 ± 0.5	2.0 ± 0.2
Triceps	2.5 ± 0.6	2.1 ± 0.3
Subscapular	2.2 ± 0.4	2.0 ± 0.2
Abdominal	2.4 ± 0.7	2.1 ± 0.3
Suprailium	2.5 ± 0.8	2.1 ± 0.3
Thigh	2.4 ± 0.5	2.2 ± 0.5

Note. Data presented as mean ± standard deviation; two is the minimum number of measurements possible.

The results from the one-sample *t*-tests comparing the measurements assessed by the students to those attained by the skilled technician revealed that for the female testee, the subscapula was the only measurement that was not significantly different from the skilled technician ($t(22) = -1.78$; $p = 0.09$), all other measure were significantly different ($p < 0.001$). In contrast, for the male testee, the SKF measurement taken by the students at the suprailium was the only measurement significantly different from the skilled technician ($t(22) = 3.40$; $p = 0.003$), all other measures were not significantly different ($p > 0.05$).

Table 2. SKF measurements (in mm) and %BF for the male and female testees.

	Female		Male	
Site	Students	Skilled technician	Students	Skilled technician
Chest	5.0 ± 2.0*	8.0	4.0 ± 1.0	4.0
Axilla	7.6 ± 1.9*	10.0	5.2 ± 0.9	5.0
Triceps	14.2 ± 3.1*	17.0	5.4 ± 1.6	5.0
Subscapular	9.5 ± 1.5	10.0	7.5 ± 1.2	7.0
Abdominal	10.7 ± 3.5*	15.0	6.6 ± 2.3	6.0
Suprailium	12.2 ± 4.0*	16.0	5.9 ± 1.2*	5.0
Thigh	14.2 ± 2.8*	19.0	5.3 ± 1.3	5.0
Total	73.3 ± 15.4*	95.0	39.9 ± 8.5	37.0
%BF	14.2 ±2.6*	17.8	4.2 ± 1.3	3.8

Note. * = significant different from skilled technician measure (p < 0.003)

The results for the Mauchly's sphericity test for the female testee indicated that the data violated the assumption of sphericity ($X2(2) = 50.2$, $p < 0.001$), so the F value was corrected using the Greenhouse-Geisser estimate. The repeated measure ANOVA showed a significant difference in absolute error among SKF sites, $F(3.35,73.58) = 12.78$, $p < 0.001$. Follow up analyses of simple effects revealed that the subscapula site had lower absolute error compared to all other sites ($p < 0.01$), and that the suprailium and thigh had higher absolute error than all other sites ($p < 0.01$) other than the abdominal site ($p > 0.05$).

The results for the Mauchly's sphericity test for the male testee indicated that the data violated the assumption of sphericity ($X2(2) = 69.5$, $p < 0.001$), so the F value was corrected using the Greenhouse-Geisser estimate. The repeated measure ANOVA showed no significant difference in absolute error among SKF sites, $F(2.6,57.2) = 1.28$, $p = 0.29$.

DISCUSSION

BC is an important component of health-related physical fitness as an undesirable BC increases the risk for cardiovascular disease (1). Therefore, the proper measurement of BC, or more specifically %BF, is essential for proper health assessment and risk stratification. To our knowledge, no research has been conducted on the validity of SKF at specific sites and BF measurements taken by novices who are learning the technique for the first time. Therefore, the purpose of this study was to determine how accurately undergraduate Exercise Science majors in an Exercise Physiology course measured SKF thickness and estimated %BF when compared to a skilled technician.

Measuring the SKFs of the female testee was the most difficult for students between the two testees which evidenced by the higher number of measurements needed for the female testee. With the exception of the subscapula, the novice students had significantly lower measurements than the skilled technician at all sites for the female testee. The suprailium, abdominal, and thigh sites had a significantly greater margin of error than most other sites. Students were able to measure SKFs of a lean male accurately when compared to the skilled technician. The one sample *t*-tests revealed only one SKF site (suprailium) where the students had a slightly yet significantly higher average measurement compared to the skilled technician. The students were also accurate when compared to the skilled technician regarding sum of SKFs and %BF estimation.

The dependence of measurement accuracy on sex of the testee may have been due to various factors. Clarys, Provyn, and Marfell-Jones (4) noted that the homogeneity of skin thickness is an underlying assumption of the SKF technique. Skin thickness at various sites has not been extensively investigated, but the sparse findings indicate that thickness is not necessarily inconsequential. Skin thickness could increase the difficulty of measurement at different sites and could contribute to the difference in error found between males and females due to the difference in thickness between sexes (13). In addition, the accuracy could have been influenced by the difference in %BF between the testees.

Table 3. Average and absolute average error between the skilled technician measurement and the students' measurements.

	Female		Male	
Site	Avg Error	Abs Avg Error	Avg Error	Abs Avg Error
Chest	-3.0 ± 2.0	3.2 ± 1.6	0.0 ± 1.0	0.7 ± 0.8
Axilla	-2.4 ± 1.9	2.7 ± 1.4	0.2 ± 0.9	0.5 ± 0.8
Triceps	-2.8 ± 3.1	3.2 ± 2.7	0.4 ± 1.6	0.8 ± 1.4
Subscapular	-0.5 ± 1.5	1.2 ± 1.0	0.5 ± 1.2	0.7 ± 1.0
Abdominal	-4.3 ± 3.5	4.9 ± 2.5	0.6 ± 2.3	1.1 ± 2.1
Suprailium	-3.8 ± 4.0	4.2 ± 3.6	0.9 ± 1.2	0.9 ± 1.2
Thigh	-4.8 ± 2.8	4.8 ± 2.6	0.3 ± 1.3	0.6 ± 1.2
Total	-21.7 ± 15.4	23.3 ± 12.7	2.9 ± 8.5	4.8 ± 7.5
%BF	-3.4 ± 2.6	3.9 ± 2.2	0.5 ± 1.3	0.8 ± 1.2

Because participants in the current study were measuring the same testees and the accuracy of measurements were compared against those of a skilled technician, we assumed that the contribution of skin thickness to measurement error was controlled (i.e., each measurement was taken on the same testees). However, skin thickness may also contribute to SKF compressibility (6). Himes, Roche, and Siervogel (9) examined SKF compressibility of 65 youth (33 males, 32 females) ages 8 to 19 years old. Although not statistically significant, the trend at most of the seven sites was for females to have less compressible SKFs than males. Hattori and Okamoto (6) examined SKF compressibility across 16 sites in 96 Japanese university students. Their findings were in partial agreement with the previous findings Himes et al. (17) and Martin et al. (14) in that limb sites tended to be less compressible in females than in males, yet the opposite was found in the trunk sites. Due to the compressibility of the skin, participants that measure the testees after multiple measures could have a measurement bias between sexes and different sites could be affected in diverse manners.

The sex-dependent nature of measurement error found in the current study also may have been affected by the difference in SKF thickness. Pollock, Jackson, and Graves (18) studied the effects of sex, SKF site location, and SKF thickness on measurement error. Participants were 24 males (ages 34 ± 10 years old) and 44 females (ages 31 ± 5 years old). After two testers on two separate days measured the axilla, chest, abdomen, thigh, subscapular, triceps, and suprailiac of the participants, Pollock et al. (18) found no sex difference. Participants were then tricotimized by the sum of SKFs with the three groups averaging 69 mm, 101 mm, and 180 mm. Measurement error was significantly higher in the group with the highest sum of SKFs. Measurement error ranged from 1.0 – 1.5 mm with SKFs under 15 mm thick, 1.5 – 2.5 mm with SKFs from 16 – 30 mm thick, and 3.0 – 3.5 mm with SKFs over 30 mm thick. Pollock et al. (17) concluded that error in the measurement of SKFs was more a function of SKF thickness than a fuction of site location or sex. In the current study, a lean male and lean female with relatively low sums of SKFs (37 mm and 95 mm for the male and female, respectively, as measured by a skilled technician) were used and testees, consequently, would have not been placed in a group where Pollock et al. found the significantly higher measurement error. However, Pollock et al. (18) identified their technicians as "trained". Therefore, it is reasonable to suspect that the measurement of thicker SKFs of the female testee, although not challenging for a trained technician, was more difficult for the students to measure and consequently resulted in greater measurement error.

The current study was carefully designed but is not without limitations. Student measurements were compared to those taken by only one skilled technician and, although our technician is highly-experienced, a degree of measurement error is always possible. The testees were both normal weight and lean, which may allow for less measurement error of the SKFs (17), although as expected the female testee had higher %BF than the male testee. More specifically, the female testee was a current member of the university's tennis team and the male testee was a former, competitive wrestler. Further research is needed on the accuracy of novices related to the measurement of heavier population with thicker SKFs, especially given the obesity epidemic in many developed countries. Also, the participants from each lab session took measurements on the same testees in a small time interval. This could make placement of the measurement more obvious and the fat may have been compressed at the later measurements.

The measurements taken by students were consistently lower for the female and yielded %BF estimations about 4% lower than the skilled technician's estimation while the students' measurements for the male were comparable to the skilled technician. Proper undergraduate education and experience with SKF measurement appears to produce students who can accurately measure SKFs, however, additional attention is necessary when teaching measurements individuals with larger SKFs with specific emphasis on the suprailium, abdominal, and thigh sites.

The goal of Exercise Science programs in higher education institutions worldwide is to produce professionals who are capable of supporting and expanding the field of exercise science. One such way is through the proper measurement of particular pertinent variables such as SKF thickness. The current study revealed that properly educated undergraduate students can accurately measure the SKFs of a lean young man and reasonably accurately measure the SKFs of a lean young woman. However, students were less accurate measuring thicker SKFs. Professionals in fields where SKFs are commonly measured (e.g., personal training, strength and conditioning) should be cognizant that interns and young professionals may not have the skills necessary to accurately measure those with thicker SKFs. Mentoring young professionals and giving them sufficient practice in SKF measurement would help them improve skill and yield more accurate results.

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