Original articles

Male and female differences in variability with estimating body fat composition using skinfold calipers

Marc P. McRae MSc, DC, FACN, DACBN*

Associate Professor, National University of Health Sciences, Lombard, IL

Received 15 January 2010; received in revised form 1 June 2010; accepted 13 July 2010

Key indexing terms:

Skinfold thickness;
Observer variation;
Reproducibility
of results;
Electric impedance;
Chiropractic

Abstract

Objective: Obesity is a major health problem in the United States. Skinfold measurements are routinely used in assessing outcomes in the management of obesity. The purpose of this study was to determine if sex differences in skinfold measurements would be apparent in intraobserver and interobserver reliability as well as validity when compared with bioelectrical impedance analysis (BIA) measurements.

Methods: To determine intraobserver and interobserver variability, 71 male and 45 female subjects (chiropractic students) were assessed by 4 separate observers who each took 4 separate skinfold measurements. Bioelectrical impedance analysis was later conducted using a foot-to-foot technique. The average sums of the skinfold measurement and their standard deviations were calculated, and correlation coefficients between skinfold measurements and BIA techniques for male and female subjects were plotted separately to assess validity.

Results: Men tended to have greater amounts of intraobserver and interobserver variability when compared with women, but these differences were not significant. In regard to validity, there was no significant difference between skinfold measurements and BIA when estimating percentage body fat for men; but the difference was significant for women, where BIA underestimated by 3.4%.

Conclusions: The differences observed in variability could be explained by the fact that there is a difference in skinfold compressibility between men and women. Physicians who are using skinfold calipers for body composition assessment should take into account these small potential differences when evaluating total body fatness.

© 2010 National University of Health Sciences.

Introduction

Obesity is a rising epidemic, as 1 in 3 adults in the United States are obese.¹ This situation creates a major health problem because of obesity's deleterious

* National University of Health Sciences, 200 E Roosevelt Rd, Lombard, IL. Tel.: +1 630 889 6592.

E-mail address: mmcrae@nuhs.edu.

association with many diseases such as hypertension, diabetes mellitus, coronary heart disease, and cancer.^{2,3} Because physical inactivity is a contributing factor in obesity, physicians should encourage patients to incorporate physical fitness into their lifestyle. Having an accurate, simple, and cost-effective tool to measure physical fitness is important, in light of the fact that a patient's self-report of fitness level is a poor indicator of actual fitness.⁴ One such simple measurement of physical fitness is the patient's body mass index. However, body mass index predicted fitness level less accurately than the measurement of percentage body fat.⁴ This suggests that incorporating an objective measurement, such as body fat composition, into the physical examination may be advantageous.

Accurately estimating percentage body fat can be made indirectly by numerous techniques, including skinfold measurements, bioelectrical impedance analysis (BIA), underwater weighing, air displacement plethysmography, isotope dilution, potassium-40 counting, dual-energy x-ray absorptiometry, ultrasonography, and magnetic resonance spectroscopy.⁵ However, most of these techniques are labor intensive and out of reach for a majority of physicians. Skinfold measurements are most popular because of the method's low cost and practicality.⁶ The technique involves measuring skinfold fat at specific anatomical sites and using these values in a regression equation to predict the subject's percentage of body fat.

The reliability of such a technique must be considered when interpreting the results from these types of evaluations, and many researchers and clinicians have questioned the results of body composition assessments performed using skinfold fat measurements.⁷ However, in support of such measurements, studies have shown intraobserver reliability to be high, ranging from 0.94 to 0.99 for repeated measurements by the same individual. Interobserver variability also ranged from 0.92 to 0.99 for repeated measurements made by different observers.⁸

In addition to reliability, the validity of the technique must be considered when interpreting results of evaluations. With respect to validity, the correlation coefficient between skinfold measurement and BIA, a well-established and valid measure of body composition, was observed to range between 0.84 and 0.92.⁹⁻¹¹

Although good reliability and validity have been established for skinfold measurement analysis using mixed-sex populations, it has not been sufficiently determined if sex differences will affect reliability and validity equally when men are compared against women. It can be hypothesized that differences would

occur because the compressibility of fat differs between men and women, with the trend for women to be slightly less compressible than men.¹² Therefore, the purpose of this study was to determine if sex differences in skinfold measurements will be apparent in intraobserver and interobserver reliability, as well as validity when compared with BIA measurements.

Methods

Subjects

This study was conducted with 71 male and 45 female first year chiropractic students. All subjects gave their informed consent and volunteered to participate in the study. This study was approved by the National University of Health Science Institutional Review Board Committee. During the prelaboratory meeting time for a first trimester clinical biochemistry laboratory, students were asked to arrange themselves into groups of 4. Within each group, students volunteered to be a subject, a data recorder, or 1 of 2 observers. During the prelaboratory meeting, a brief discussion about the experiment was presented; and a 2-page instruction guide on taking skinfold measurements with Lange calipers (Beta Technology, Santa Cruz, CA) was provided to all students.

Anthropometric assessment

To demonstrate intraobserver and interobserver variability, the subject was assessed by 4 separate observers (to determine interobserver variability) who each took 4 separate skinfold measurements (to determine intraobserver variability) using the Lange skinfold calipers. The skinfold measurement obtained from each separate observation was based on the sum of 4 skinfold sites (bicep, triceps, subscapular, and suprailiac). The subject's percentage body fat was obtained using the sum of skinfolds from the tables designed for the Lange skinfold calipers. When these measurements were completed, each subject underwent BIA assessment.

Bioelectrical impedance analysis

Total body resistance was measured with a foot-to-foot bioelectrical impedance analyzer (UM-026; Tanita Corp, Tokyo, Japan) at a fixed signal frequency of 50 kHz and 500 μ A. The subjects'

Table 1 Comparison of intraobserver and interobserver variability across sex

Sex	No. of subjects	Mean age (y)	Mean weight (lb)	Intraobserver variability (mm)	Interobserver variability (mm)
Male	71	25.1	185.5 ± 29.2	4.7 ± 2.3	9.9 ± 6.3
Female	45	24.9	132.2 ± 17.8	4.4 ± 2.0	9.7 ± 5.6

No statistical difference was found across sex for intraobserver and interobserver variability.

height, age, and sex were entered into the BIA device. The subject's percentage body fat was estimated by the manufacturer's equation that was digitally displayed and recorded.

Statistical analysis

Descriptive statistics included calculation of mean values and standard deviations for male and female subjects for age, weight, and percentage body fat estimated from skinfold and BIA. Correlation coefficients were also calculated for both male and female comparisons between skinfold and BIA techniques. To find individual differences between the skinfold and BIA analysis, the Bland-Altman procedure was calculated and illustrated. Statistical analysis was performed using *t* tests to compare mean values, and *P* values < .05 were considered to be statistically significant.

Results

The descriptive data for the subjects as well as the intraobserver and the interobserver variability results are presented in Table 1. The relationships between the skinfold measurements and the BIA for men and women are illustrated in Figs 1 and 2. The correlation coefficient was lower for men compared with women (0.70 vs 0.84, respectively) (Table 2). Figs 3 and 4

display the difference in body fat against average body fat for the 2 methods and show considerable agreement between skinfold measurements and BIA, as 93% of differences lie between limits of agreement (mean ± 2 SD).

Discussion

Compared with female subjects, the intraobserver and interobserver variabilities were both greater for the male subjects; but this difference was not statistically significant. This difference could be explained by the finding that there is significant variability in skinfold compressibility among men, but less corresponding variability in women skinfold compressibility.¹² It has been previously noted that the compressibility of fat differs between men and women, with the trend for women to be slightly less compressible than men. This could account for the greater intraobserver and interobserver variability in men compared with women as was observed in this study. This variability in skinfold compressibility may be due to differences in the distribution of fibrous tissue and blood vessels in the subcutaneous tissue mediated through genetic and/or hormonal differences between men and women.

Skinfold measurements showed good validity with respect to BIA for men, but not for women. For women, BIA estimated percentage body fat on average as being

Fig 1. Relationship of percentage body fat between skinfold measurements (SKF) and BIA for men (*n* = 71). *R* = 0.700.

Fig 2. Relationship of percentage body fat between SKF and BIA for women (*n* = 45). *R* = 0.837.

Table 2 Comparison between skinfold measurements and BIA to determine validity for men and women

Sex	No. of subjects	Estimated percentage body fat, SKF (%)	Estimated percentage body fat, BIA (%)	Pearson correlation coefficient
Male	71	20.7 ± 4.8	20.4 ± 5.5	0.700
Female	45	28.5 ± 5.2	25.1 ± 7.3 *	0.837

SKF, Skinfold measurements.

* $P < .001$ for comparison between SKF and BIA methods.

3.4% lower when compared with skinfold measurements. This could be attributed to the female group in this study being a little more on the athletic side; and therefore, the BIA underestimated their percentage body fat in comparison to skinfold measures because the device uses an algorithm that was designed from a “normal” population who in comparison may not have been as athletic and a little more overweight. This illustrates one of the drawbacks for this technique, as the BIA will only be as good as the norms on which it is based.

The correlation coefficients observed between skinfold measures and BIA was opposite of what was expected based on the past literature. In this study, the female subjects had a correlation coefficient of 0.84, whereas the men had a coefficient of 0.70. Previous studies comparing skinfold measures and BIA found a correlation of 0.78 for women¹³ and 0.96 for men.¹⁴ In a study comparing skinfold measurements and magnetic resonance imaging, they found no significant difference in the correlation coefficients between women and men (0.90 and 0.88,

Fig 3. Bland-Altman analysis of the difference between body fat measurements using SKF and BIA for men. Data are individual differences between 2 methods for 71 subjects. Ninety-three percent of the subjects lie between the ± 2 standard deviation limits set above. **Fig 4.** Bland-Altman analysis of the difference between body fat measurements using SKF and BIA for women. Data are individual differences between 2 methods for 45 subjects. Ninety-three percent of the subjects lie between the ± 2 standard deviation limits set above.

respectively).¹⁵ The fact that the correlation coefficient in our study was observed to be lower in men compared with women can probably be attributed to the higher variability in skinfold measurements as previously noted.

Limitations

This study is not without its limitations. First and foremost, this study used inexperienced caliper operators; and the intra- and interobserver variability obtained with this inexperienced group was considerably greater than the variability observed with experienced caliper operators.⁸ A review article using approximately 25 published articles on skinfold measurements was used for comparison.¹⁶ The pooled intraobserver variability for the experienced observers from the review article was 3.43 mm vs 4.58 mm for the inexperienced observers in this study. The pooled interobserver variability for the experienced observers from the review was 5.39 mm vs 9.78 mm for the inexperienced observers in this study. It is evident that the discrepancy between experienced and novice caliper operators for interobserver variability is considerably different, suggesting a wide disparity of skill within the inexperienced observers in this study. Therefore, in the future, it is important that caliper operators obtain enough training to achieve and maintain a standardized technique to reduce the intraobserver and especially the interobserver variability.

Another limitation of this study is based on the possibility that the repetitive measurements taken on

the subjects may result in the expulsion of water from the adipose tissue at the site of the measurement. Therefore, over the short period that the measurements were taken, this compressive fluid loss could gradually increase both the intra- and interobserver variability.¹⁶ Finally, the taking of multiple measurements could lead to either the possibility of fatigue setting in, which could increase the chances of the observers making mistakes, or the possible loss of calibration of the calipers throughout the experiment.

Conclusion

Calipers do not necessarily measure absolute fat thickness; but if used at a number of good sites, they can provide an indication of overall body fatness. Calipers provide a simple means of monitoring body composition changes and can provide a useful measurement for monitoring the outcomes of diet and exercise programs. But because tissue compressibility varies across sex, physicians who are using skinfold calipers for body composition assessment should take into account these small potential differences when evaluating total body fatness.

Funding sources and potential conflicts of interest

No funding sources or conflicts of interest were reported for this study.

References

1. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. *JAMA* 2006;295(13):1549-55.
2. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. *JAMA* 1999;282(16):1523-9.
3. Sullivan PW, Ghushchyan VH, Ben-Joseph R. The impact of obesity on diabetes, hyperlipidemia and hypertension in the United States. *Qual Life Res* 2008;17(8):1063-71.
4. Heimmell J, Patel S, Cody R, Bachmann G. Evaluation of physical fitness in an ambulatory setting. *Am J Obstet Gynecol* 2007;196:522-3.
5. Lee SY, Gallagher D. Assessment methods in human body composition. *Curr Opin Clin Nutr Metab Care* 2008;11(5):566-72.
6. Ketel IJ, Volman MN, Seidell JC, Stehouwer CD, Twisk JW, Lambalk CB. Superiority of skinfold measurements and waist over waist-to-hip ratio for determination of body fat distribution in a population-based cohort of Caucasian Dutch adults. *Eur J Endocrinol* 2007;156(6):655-61.
7. Kispert CP, Merrifield HH. Interrater reliability of skinfold fat measurements. *Phys Ther* 1987;67(6):917-20.
8. Jackson AS, Pollock ML, Gettman LR. Intertester reliability of selected skinfold and circumference measurements and percent fat estimates. *Res Q* 1978;49:546-51.
9. Kushner RF, Haas A. Estimation of lean body mass by bioelectrical impedance analysis compared to skinfold anthropometry. *Eur J Clin Nutr* 1988;42(2):101-6.
10. Vansant G, Van Gaal L, De Leeuw I. Assessment of body composition by skinfold anthropometry and bioelectrical impedance technique: a comparative study. *J Parenter Enteral Nutr* 1994;18(5):427-9.
11. Martin MV, Gomez JB, de Oya OM, et al. Interchangeability of the fat-to-fat-free mass ratios obtained by means arm anthropometric measures, skinfold thickness, and bioelectrical impedance. *Nutr Hosp* 2003;18(2):77-86.
12. Himes JH, Roche AF, Siervogel RM. Compressibility of skinfolds and the measurement of subcutaneous fatness. *Am J Clin Nutr* 1979;32:1734-40.
13. Kitano T, Kitano N, Inomoto T, Futatsuka M. Evaluation of body composition using dual-energy x-ray absorptiometry, skinfold thickness and bioelectrical impedance analysis in Japanese female college students. *J Nutr Sci Vitaminol* 2001;47(2):122-5.
14. Ostojic SM. Estimation of body fat in athletes: skinfolds vs bioelectrical impedance. *J Sports Med Phys Fitness* 2006;46:442-6.
15. Hayes PA, Sowood PJ, Belyavin A, Cohen JB, Smith FW. Subcutaneous fat thickness measured by magnetic resonance imaging, ultrasound and calipers. *Med Sci Sports Exerc* 1988;20(3):303-9.
16. Ulijaszek SJ, Kerr DA. Anthropometric measurement error and the assessment of nutritional status. *Br J Nutr* 1999;82(3):165-77.