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Validity and Reliability of Body Composition Analysis Using the Tanita BC418-MA

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ABSTRACT

Kelly JS, Metcalfe J. Validity and Reliability of Body Composition Analysis Using the Tanita BC 418 MA. **JEPonline** 2012;15(6):74-83. This investigation compared measurements of percentage body fat (%BF) by bioelectrical impedance analysis (BIA) using the TANITA BC418-MA (TAN) with hydrostatic weighing (HW), and skinfold thickness (ST) (Study 1). In addition, the same-day test-retest reliability of the TAN system was assessed (Study 2). For Study 1, a sample of 28 male and 29 female subjects were recruited. TAN, HW, and ST were used to assess %BF with the same experimenter completing all assessments in a counterbalanced order. In Study 2, 24 males and 28 females had %BF measured on two occasions using the TAN to establish the same-day test-retest reliability of the system. Results for Study 1 indicated that TAN and ST recorded significantly different mean %BF compared to HW, with %BF being overestimated by 1.68% using TAN and 1.49% using ST. Despite strong correlations between TAN and HW (r = 0.81; P<0.05) there was relatively poor agreement between the %BF measurements from TAN and HW (±9%), although the level of agreement between ST and HW was little better (±8%). The same-day test-retest reliability of TAN was good with no mean bias from test to test and excellent limits of agreement (<1%). In conclusion, the TANITA BC418-MA is a reliable system, which has poor agreement with laboratory-based methods of assessment (HW). However it is on a par with assessment by skinfold thickness and provides a non-invasive alternative, which requires less operator training.

Key Words: BIA, Body Composition

INTRODUCTION

The accumulation of excess adipose tissue in adults is independently associated with an increased risk for many chronic health conditions, including hypertension, diabetes, coronary heart disease, and stroke (23,24). Current evidence suggests that this is also the case for children and young adults (8,10,12). The relationship between body fat (BF) and the risk of chronic disease is stronger for a centrally distributed pattern of fat deposition compared to that in lower body segments (6,14,17). Despite the role of abdominal obesity in the development of many chronic diseases and disabilities, an accurate and reliable assessment of percentage body fat (%BF) is still not readily available outside of research institutions.

In practical, terms the measurement of %BF or body composition needs to be inexpensive, non-invasive, operator friendly, and gives highly reproducible and accurate results (2). Assessment methods that demonstrate the most accurate and reliable results are Computed Tomography (CT), Hydrostatic Weighing (HW), and Dual-Energy X-ray Absorptiometry (DEXA). Hence, these methods are considered as reference standards (1,13,25). The problem, however, with the technology is that they are prohibitive in most practical situations due to high costs and the need for laboratory space, operator training and experience. In addition, these methods do not eradicate the possibility for measurement error (11).

Other methods predict body composition using regression analysis against a reference standard. Although these field-based methods allow for a quick estimation of body composition, they may compromise validity and reliability to some extent. Traditionally, the assessment of body composition in the field has been by skinfold caliper. This popular technique is relatively simple, inexpensive, and may be used in many situations. The degree to which skinfold measurements provide a valid assessment of body composition has been investigated previously (5,18), showing correlation coefficients as high as 0.931 when compared with HW (18). Using different statistical techniques (4,19), more recent studies have shown less agreement between skinfold thickness (ST) measurements and measurements made using other reference methods (2,15,28). Batterham et al. (2) highlighted a consistent underestimation of body fat in HIV patients, with the bias being as high as –8.87 %BF with an error of 4.95 %BF. These findings were reported despite data exhibiting a strong correlation between ST measurements and DEXA (r=0.810).

Bioelectrical Impedance Analysis (BIA) is increasingly used to assess body composition, primarily because it is relatively cheap, quick, non-invasive, and requires limited operator training. With advances in technology and refined prediction equations, the assessment of body composition by BIA shows similar levels of agreement with standard reference methods and other field based techniques (9,15,21,28). Early BIA systems suffered from technical and practical limitations with, for example, a 1 cm displacement of electrodes resulting in a 2% change in resistance (7). An important development in BIA was the introduction of contact electrodes, which negated the need for stainless steel paste-on electrodes. This is more convenient for subjects and reduces error in resistance measurement (20,26).

Jebb et al. (15) evaluated the TANITA 305 body composition analyzer (Tanita Corp., Tokyo, Japan) that uses contact electrodes. This machine demonstrates reasonable agreement (bias of +0.9% body fat, 2 SD 10.2% body fat) with a four-compartment model, which included DEXA. A further development is the use of 8-point contact systems that improve the association between BIA and reference standards (21), thus allowing for segmental body composition analysis. The TANITA BC418-MA (Tanita Corp., Tokyo, Japan) is an 8-contact electrode system capable of acquiring segmental body composition analysis without the need for gel electrodes. It has been shown that the

TANITA BC418-MA provides a valid measure of body composition when compared to DEXA using segmental analysis (21).

The aim of this investigation was to determine the validity of the TANITA BC418-MA (TAN) body composition analyzer against HW and ST (Study 1) and then, subsequently, to determine the same-day test-retest reliability of the TAN (Study 2).

METHODS

Subjects

Study 1: Validity of TAN to Determine Percentage Body Fat

A sample of 28 male subjects (age 24 ± 8 yrs, height 1.76 ± 0.09 m, mass 75.4 ± 14.5 kg) and 29 female (age 22 ± 6 yrs, height 1.70 ± 0.10 m, mass 67.2 ± 10.7 kg) were recruited following initial health screening. Prior to any measurements, the subjects were informed of the nature of the tests and were asked to adhere to a pretest protocol that which included a 12-hr fast, abstinence from alcohol for 24 hrs, no exercise for 24 hrs, and to attend adequately hydrated. Females were assessed between 6-10 days following menses to control for fluid overload states. Adherence to these criteria was verbally confirmed with the subjects prior to participation. Each subject provided written informed consent following a full explanation of the study procedures, which were approved by the University Research Ethics Committee.

Study 2: Reliability of TAN to Measure Percentage Body Fat

The reliability of %BF measurements obtained from the TAN was examined in a separate subject cohort. Following ethical approval, informed consent and health screening, 24 males (age 38 ± 12 yrs, height 1.79 ± 0.07 m, mass 82.80 ± 13.59 kg) and 28 females (age 45 ± 11 yrs, height 1.65 ± 0.08 m, mass 61.88 ± 10.46 kg) had their percentage body fat measured on two occasions using the TAN.

Procedures

Study 1: Validity of TAN to Determine Percentage Body Fat

Subjects attended the laboratory on one occasion, during which they had body composition estimated by three different methods (HW, TAN, and ST). The tests followed a counterbalanced order with the same experimenter taking all measurements and recordings. The experimenter had previous experience of body composition analysis, and was familiar and well-practiced with the techniques used in this study. The subjects were required to wear a swimsuit during the tests. The following measurements were recorded prior to body composition analysis: height (m), mass (kg), room temperature (°C), and barometric pressure (mmHg).

Study 2: Reliability of TAN to Measure Percentage Body Fat

Subjects attended the laboratory on a single session during which percentage body fat was measured twice. Both recordings were made within 15 min of each other. During the 15-min period, the subjects refrained from any physical activity but were free to move around the laboratory.

Bioelectrical Impedance Analysis

Measurements using the TAN segmental body composition analyzer were recorded following a standardized 10-min standing period to minimize acute shifts in fluid distribution (7). Subject details were entered into the TAN, including information on clothing weight, gender, age, and height. When prompted, subjects stepped onto the footpads and grasped the handles. Analysis took approximately 10 sec during which time the subjects remained still and relaxed. Measurements were recorded in the standard mode.

Hydrostatic Weighing

HW was conducted using a 1.67 m^3 immersion tank, a wire mesh cradle, and a single point Salter Digital Balance model 2G-100. Following emersion in the hydrostatic tank, subjects removed trapped air in their swimsuits. Subjects lay supine on a wire cradle fully submerged and were instructed to forcefully exhale through a lightweight mouthpiece and tubing. At the end of the exhalation, mass was recorded. This procedure was repeated until 2 measurements were within ±50 g. The Archimedes principal was used to calculate body volume with an appropriate correction factor applied for residual lung volume (1) and GI volume assumed to be 100 mL (16). Body density was then calculated from the volume value (body mass/volume), and was entered into the Siri (22) equation for estimation of percentage body fat.

Skinfold Thickness

Skinfold thickness was measured using a Harpenden Skinfold Caliper (Harpenden, England). Measurements were taken from the chest, supra-illiac, and triceps for males, and from the abdomen, supra-illiac, and triceps for females according to the published guidelines (1). Generalized skinfold equations (1) were used to predict body density. %BF was estimated using the equation of Siri (22).

Statistical Analyses

Body composition data are presented as means ± SD for all subjects and by gender. The percentage body fat measurements of the field-based methods, TAN, and ST were statistically correlated with HW using Pearson's correlation coefficients. After checking the data for normal distribution and heteroscedasticity, the assessment of bias and limits of agreement for both Study 1 and Study 2 were analyzed using paired sample t-tests and Bland-Altman plots. The interaction between gender and mode of assessment was investigated using 2-way mixed design ANOVA. Inferential statistics were considered significant when P<0.05.

RESULTS

Validity of TAN to Determine Body Fat Percentage: Whole Group Analysis

Mean %BF, as measured by the Tanita BIA system, was significantly different from HW (Table 1). TAN overestimated %BF by 1.68% ($t_{(56)}$= -2.762, P=0.008). %BF as measured by ST was also significantly different from HW ($t_{(57)}$= -2.692, P=0.009), overestimating by 1.49% BF. There were strong significant correlations between TAN and HW (r_p=0.81, P<0.0005) and between ST and HW (r_p = 0.80, P<0.0005).

Table 1. Measures of Percentage Body Fat by HW, ST, and TAN. Values are means ± SD. HW, Hydrostatic Weighing; ST, Skinfold Thickness; BIA, Bioelectrical Impedance Analysis. *Significantly different from HW.

All subjects (n=57)	HW% BF	ST% BF	TAN% BF
Mean	19.19 ± 0.86	20.68 ± 0.88 *	20.87 ± 1.04 *
Min – max	5.90 - 32.20	5.60 - 33.20	5.80 - 38.00
Range	26.30	27.60	32.20

Validity of TAN to Determine Body Composition in Males and Females

There were significant correlations (ranging from 0.543 to 0.821) between all methods for both males and females. A 2-way ANOVA showed significant differences for the main effect of gender

($F_{(1,55)}$=52.251, P<0.0005) and for the main effect of method ($F_{(1,55)}$=5.650, P=0.005). The gender by method interaction also showed a significant difference and pre-planned t-tests indicated that for males, ST was significantly different to HW and TAN, but TAN was not different from HW (Table 2). In females, TAN was significantly different to both HW and ST, but there was no difference between HW and ST (Table 3). Table 4 shows the mean bias and limits of agreement for all subjects and both males and females. While there is a small negative bias for TAN and ST compared to HW for the group as a whole and for men and women, the limits of agreement are large ranging from 7.11% BF to 9.58% BF.

Table 2. Measures of Percentage Body Fat in Males.

Males(n=28)	HW	ST	TAN
Mean	15.11 ± 1.01	16.72 ± 1.00*	15.04 ± 0.92
Min – max	5.90 - 27.10	5.60 - 30.70	5.80 - 26.40
Range	21.20	25.10	20.60

Values are means ± SD. HW, Hydrostatic Weighing; ST, Skinfold Thickness; BIA, Bioelectrical Impedance Analysis. *Significantly different from HW.

Table 3. Measures of Percentage Body Fat in Females.

Females (n=29)	HW	ST	TAN
Mean	23.13 ± 0.91	24.5 ± 0.92	26.5 ± 1.08*
Min – max	13.50 - 32.20	13.10 - 33.20	13.80 - 38.00
Range	18.70	20.10	24.20

Values are means ± SD. HW, Hydrostatic Weighing; ST, Skinfold Thickness; BIA, Bioelectrical Impedance Analysis. *Significantly different from HW.

Table 4. Mean Bias and 95% Limits of Agreement for Percentage Body Fat (TAN and ST relative to HW).

	Whole Group		Male		Female	
	Bias	LOA	Bias	LOA	Bias	LOA
TAN	-1.68	9.00	0.07	9.58	-3.37	7.11
ST	-1.49	8.21	-1.61	7.43	-1.38	9.02

Study 2: Reliability of BIA to Measure Percentage Body Fat

The reliability of the TAN to assess body composition was investigated. A good level of reliability was demonstrated with a test re-test coefficient of variation of 1.4%. There was no significant difference between mean scores, 23.38% BF for trial 1 and 23.37% BF for trial 2. Bland and Altman analysis gave an overall bias of 0.02% BF and 95% confidence limits of 0.91% BF (Figure 1).

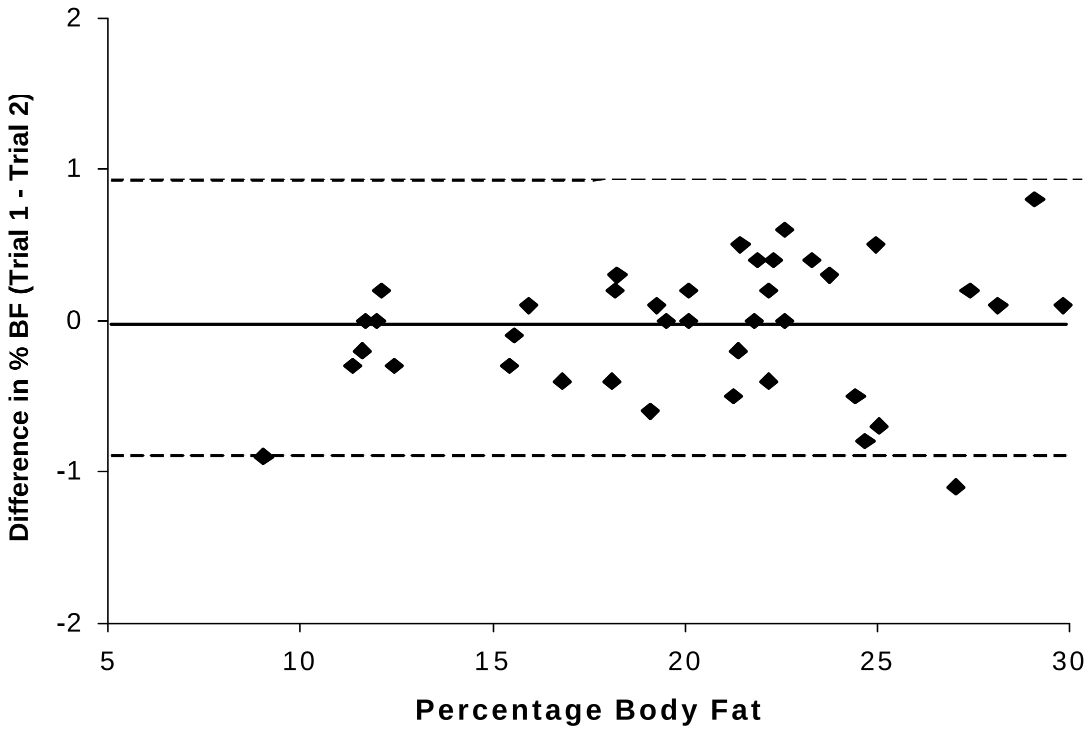

Figure 1. Bland and Altman Plot. Trial 1 and Trial 2 using the Tanita BC418-MA

DISCUSSION

The accurate determination of body composition requires expensive equipment and complex and time consuming methods (e.g., DEXA or HW) that are often beyond the scope of most clinical and health-based practice. Thus, most clinical, health, and/or exercise physiology professionals rely upon estimates such as body mass index or, at best, the measurement of ST to determine changes in body fatness. Problems exist with BMI in that two individuals might have the same BMI but different body compositions. While the determination of body composition through the measurement of ST does alleviate this problem, subjects (particularly overweight or obese subjects) often feel self-conscious about having these measures taken and might avoid participating in studies where the measurement of ST is a requirement. That is why a simple non-invasive method of determining percentage body fat would be of value to clinical and healthcare based practice as well as research. However, for these methods to be of the greatest practical use, the measurements must be inexpensive, non-invasive, operator friendly and, most of all, reliable (2).

BIA has been used with increasing frequency for the determination of body composition because it is quick, inexpensive, non-invasive, and requires limited expertise. BIA initially suffered bad press due to technical and practical limitations, although recent advances in technology and refined prediction equations have significantly improved the technique (9,15,21,28).

This study has evaluated the validity of the TANITA BC418-MA in relation to two other accepted and well-used methods (hydrostatic weighing and skinfold thickness) for the determination of body composition in a cohort of 57 male and female subjects. Moreover, this study measured the same-day reliability of the TANITA BC418-MA in a separate cohort of 52 male and female subjects. Thus, we have added to the one study (21) that has already examined the validity of the TANITA BC418-MA against DEXA and other studies examining the validity of earlier TANITA systems (15).

The results for the whole group showed that both TAN and ST recorded significantly different mean %BF when compared to HW, with TAN overestimating %BF by 1.68% and ST overestimated BF by 1.49%. Other methods, for example DEXA, have shown better agreement with TAN. Pietrobelli and colleagues (21) showed no significant mean bias when comparing body fat measured by the TAN and DEXA. This may be because DEXA provides a more accurate measure of body composition than hydrostatic weighing, although the absolute accuracy of DEXA has not been confirmed by chemical analysis of cadavers. Even though no significant differences in mean %BF where reported in the Pietrobelli et al. (21) study, there were large differences in the mean values. For example, the mean difference between TAN and DEXA for estimation of the left arm fat percentage was 3.8% BF; 26.6 ± 12.1% for TAN compared to 30.4 ± 10.3% for DEXA. These values are larger than the differences reported in the present study. Despite strong correlations observed between TAN and HW in our study ($r = 0.81$; $P<0.05$), there was relatively poor agreement between %BFs from TAN and HW (±9%, as shown in Table 2). Associations of this order have been reported elsewhere (3,21,27). Pietrobelli et al. (21) concluded that there was no between method bias and that there were strong correlations between the different methods of %BF assessment. However, they failed to report the limits of agreement between methods as suggested by Bland and Altman (4).

van Marken Lichtenbelt et al. (27) validated several methods of body composition analysis, including BIA against a 4-component model. They concluded that descriptive methods, such as ST, BIA, and DEXA, gave typical errors ranging from 5.5% BF to 8% BF. The magnitude of the limits of agreement observed in our study would seem to be in line with these findings and the findings of others (3). Of importance in our study was that the agreement between ST and HW was no better (±8.21) than that between TAN and HW. This highlights the potential for the use of BIA over the more invasive and technically more difficult method of ST.

The group findings for male and females showed differing results. Not surprisingly, there was a difference in body composition between the groups. However, males showed essentially no mean bias between HW and BIA (15.11% BF vs. 15.04% BF) while females did (23.13% BF vs. 26.5% BF). This difference, while statistically significant, equates to a clinically small difference of approximately 2%. However, this gender difference has been shown in other studies (3). Males and females displayed similar limits of agreement, ranging from 7.11% BF to 9.58% BF. These values are similar to previous studies (3,15,20,27), and they indicate that the TAN is associated with similar variation relative to other methods of body composition assessment. In practical terms, the errors that occur between differing methods of assessment may occur for a variety of reasons, including investigator error, but may also reflect the different algorithms and prediction equations which have been established for each method.

The second part of this investigation established the reliability of the TAN. Above all else, the healthcare practitioner needs reliable methods of assessment, whether that is lifestyle questionnaires, blood pressure monitors, or body composition analyzers. It should be apparent that this study has demonstrated that the TAN is a reliable piece of equipment. Our results show no mean bias from test to test and very acceptable limits of agreement.

CONCLUSIONS

The TANITA BC418MA provides the healthcare practitioner with a reliable method for assessing body composition in both males and females and, while there are significant interactions between gender and method of assessment, they do not represent a clinical obstacle to using this system. In addition, coupled with its ease of use, and less invasive nature makes it suitable for assessment of body composition in vulnerable populations such as children and the obese.

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