Relationship Among Three Field Methods of Estimating Percent Body Fat in Young Adults

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ABSTRACT
A certain amount of fat is essential for normal body functioning and subcutaneous fat is usually considered to represent a good estimate of total body fat. It is uncertain, however, whether the different field methods of estimating percent body fat will give similar values, considering the variations in the methods used in the assessment. This study sought to determine the relationships among percent body fat value estimates obtained using skinfold thickness (ST), body circumference (BC), and bioelectrical impedance analysis (BIA).

This cross-sectional survey involved purposefully selected participants from the University College Hospital, Ibadan community. Skinfold thickness, body circumference and bioelectrical impedance analysis were measured according to the International Standards for Anthropometric Assessment protocol. These were then used to estimate percent body fat. The relationship among the different percent body values were sought using Pearson correlation coefficients.

The participants included 75 males and 93 females with a mean age of 25.5±5.0 years. Using the BMI classification of body weight, 50% had desirable weight, 23.8% were underweight, 15.6% were overweight, and 10.7% were obese. The mean percent body fat scores obtained from ST, BC and BIA were 19.8±6.3%, 18.5±7.1% and 18.4±8.0% respectively. Females had significantly higher percent body fat in all the estimates than their male counterparts. There were significant correlations between percent body fat obtained using ST and BIA ($r = 0.86$, $p < 0.05$), BC and ST ($r = 0.90$, $p < 0.05$), and BIA and BC ($r = 0.74$, $p < 0.05$). Positive and significant correlations exist among percent body fat obtained using the skinfold thickness, body circumference and bioelectrical impedance analysis methods. Therefore, all these methods are acceptable for clinical estimation of percent body fat. This study shows that the estimation of percent body fat can be done using both sophisticated and simple instruments.

Keywords: *Body mass index, skinfold thickness, body circumference, bioelectrical impedance analysis*

INTRODUCTION

A certain amount of fat is essential for normal body functioning and subcutaneous fat is usually considered to represent a good estimate of total body fat.[1] Body composition partitions the body into lean mass and fat mass. Fat mass is a primary concern in health care because obesity and being overweight are associated with health problems such as heart disease, diabetes mellitus, osteoporosis, gout, cancer and osteoarthritis.[2] The degree of body fat is measured as percent body fat, which is the percentage of the body weight accounted for by fat.[3,4,5]

Percent body fat can be measured using laboratory methods, which include hydrostatic weighing, near infrared reactance, magnetic resonance imaging, ultrasound assessment, computer tomography and dual energy x-ray absorptiometry or field methods such as skinfold thickness measurement, body girth measurement and bio-electrical impedance analysis (BIA).[1,6] Most of the field methods have been shown to correlate well with underwater hydrostatic weighing.[6] However, it is uncertain whether the different field methods of estimating percent body fat will give similar values, considering the variations in the methods used in the assessment. For example, while the bioelectrical impedance analysis estimates the body fat through impedance/resistance to current flow in the body, skinfold thickness and body circumference measure-ments use regression equation models to predict body fat.[6] In view of this the three methods may not predict similar values of percent body fat. This is of clinical significance, especially in developing countries where there is relative scarcity of sophisticated equipment and measurements need to be taken using skinfold calipers and fat monitors required for some of the field methods. This study therefore investigated the relationships among estimated percent body fat in apparently healthy Nigerian young adults using three field methods.

METHODS

This study was approved by the joint ethical committee of the university and its teaching hospital. The participants for the study were 168 (93 females and 75 males) apparently healthy young adults between 18 and 29 years. They were recruited from the students and staff of the University College Hospital, Ibadan community, using the purposive sampling technique. All individuals who volunteered for the study were further interviewed and physically examined. Those who presented with fever, cold, oedema, paralysis, or hyperhydrosis; those with pacemakers; women in their menstrual period and pregnant women were excluded from the study. The participants who met the inclusion criteria signed the informed consent form before they were allowed to participate in the study.

Four measurements: height and weight for body mass index (BMI), body circumference, skinfold thickness and bioelectrical impedance analysis (BIA) were obtained from each participant. The BMI was used to classify participants into desirable weight, underweight, overweight, and obese.[7] The Omron body fat monitor was used as a BIA device, while the skinfold caliper and a non-detractable tape measure were used for skinfold thickness and body girth measurements respectively. The overall possible relationship between percent body fat estimations from body circumference and skinfold thickness measurements and the BIA were sought. Also the relationships among percent body fat estimates from the body circumference measurement, skinfold thickness measurement and BIA in relation to the different body weight types (BMI) were separately sought. All measurements were carried out on the same day by one of the researchers (YOB). The measurements were completed within 25 to 50 minutes for each participant.

The age of the participants as at their last birthday was recorded. The weight was measured to the nearest 0.1 kilogram with a portable weighing scale (Secca, Germany), while the height was measured to the nearest 0.5 centimeters using a detachable plastic height meter (Secca, Germany). Both measurements were taken using the International Standards for Anthropometric Assessment (ISAK) protocol[8] and the body mass index was calculated as the weight in kilogram divided by the height in meters squared.[8] Body girth was measured with a flexible non-elastic cloth tape. All measurements were done on the right side of the body. The sites of measurement for young men between 18 and 26 years were the right upper arm (2.5 cm below the acromia), the abdomen (2.5 cm below the umbilicus) and the right forearm (mid point between the shoulder and the elbow). Measurements were taken on the right thigh (2.5cm below the buttocks), the abdomen (2.5 cm below the umbilicus) and the right forearm (mid point between the shoulder and the elbow) for females. For males between 27 and 50 years, the sites of measurement were the hips, abdomen and the right forearm.[8] For the females of this age group, measurements were taken on the right thigh, the abdomen and the right calf (widest girth mid-way between ankles and knees).[8] Skinfold thickness was measured to the nearest millimeter using the Lange caliper (Cambridge Industries, Maryland) at the following sites: triceps, biceps, sub-scapular and supra-iliac. All measurements were taken on the right side of the body while participants were standing.[8] Three skinfold measurements were taken at each site and the average of the two closest values recorded as the fat fold score for that site.[8] The percent body fat of the participants was estimated from the sum of the four skinfold measurements, using the table developed by Durnin and Womersley.[9]

The bioelectrical impedance analysis for this study utilized the fat monitor (OMRON BF- 32) device. The measurements were taken with participants standing with feet slightly apart while holding the body fat monitor in both hands and pressing firmly against the electrodes with the shoulders flexed at 90° and the elbows in maximum extension. The participants maintained this position until the instrument displayed the percent body fat based on the weight, height, age and gender of the participant. To calculate the percent body fat from the body circumference measurements, the age and sex specific conversion equation derived by McArdle et al.[6] was used.

DATA ANALYSIS

Descriptive statistics of mean and standard deviation were used to place participants in body weight (BMI) categories. Pearson product moment correlation coefficients were calculated to investigate the relationship of the percent body fat scores obtained to skinfold thickness, body circumference measurements and bioelectrical impedance analysis. The Pearson product moment correlation coefficient was also used to find out the relationship between body weight (BMI) and percent body fat scores obtained from skin fold thickness, body circumference measurements and BIA. The independent t-test was used to compare the difference in percent body fat estimates as measured from skin fold thickness, body girth measurement and BIA between male and female participants. The one-way ANOVA was used to ascertain if significant differences exist in the percent body fat estimates of skin fold thickness, body circumference measurements and BIA according to body weight (BMI) types ($p < 0.05$).

RESULTS

Using body mass index to categorize participants into body weight, 50% had desirable weight, 23.8% were underweight, while 15.6% were overweight and 10.7% were obese. The physical characteristics of the participants are presented in table 1. Table 2 shows percent body fat as measured using the three methods. The mean percent body fat scores of skin fold thickness measurement, girth measurement, and BIA were 19.8± 6.3%, 18.5±7.1% and 18.4±8.0% respectively. Female participants had significantly higher percent body fat estimates from the three methods than their male counterparts (table 2).

Table 3 shows the difference in percent body fat estimates from the three methods by body weight (BMI) categories. Significant differences only exist in percent body fat estimates from the three methods in underweight body participants. Post hoc analysis of percent body fat estimates from the three methods by body weight, however implicated the difference to be between the skin fold thickness and BIA techniques.

Table 1. Demographic characteristics of participants (n=168)

Variables	Male (n=75)	Female (n=93)	Total (n=168)
Age (yrs)			
Mean±SD	25.1±5.1	25.9±5.0	25.5±5.0
Weight (kg)			
Mean±SD	70.0±13.8	60.2±13.6	64.6±14.9
Height (m)			
Mean (SD)	1.70±0.05	1.62±0.06	1.65±0.07
BMI (kg/m^2)			
Mean±SD	24.3±4.8	23.3±5.0	23.6±5.0

Table 2. Percent body fat of participants

Methods	Male Mean ± SD	Female Mean ± SD	t-value	p-value
Skin fold thickness	13.9± 6.5	25.7±6.1	- 12.012	0.000
Body circumference	14.2±7.3	22.8±6.9	- 7.870	0.000
Biolectrical impedance analysis	14.3±8.5	22.4±7.4	- 6.595	0.000

p < 0.05

The percent body fat estimated from the skin fold thickness was found to be significantly related to that estimated from BIA ($p<0.05$). A significant correlation was also found between percent body fat composition estimated from body circumference measurements and that of skin fold thickness ($p<0.05$). Also, a significant correlation was found between percent body fat composition of BIA and body circumference measurements ($r=0.742$). The correlation coefficients between estimated percent body fat from the three methods were high for the different body weight (BMI) categories (table 4).

DISCUSSION

The present study investigated the relationship between three field methods of estimating body fat composition in adult Nigerians. The results suggest that similar values of percent body fat were obtained using the three methods in apparently healthy young adult Nigerians. This finding corroborates those of previous studies that body circumference measurement is an easy and useful tool for assessing body adiposity.[10,11,12] Hughes et al.[13] also reported that waist and hip circumference measurements were better anthropometric predictors of change in body fat mass over a 10-year period than changes in skin fold thickness. A few other studies have also shown that body circumference measurements correlate well with amount of visceral fat in young and older persons.[12,15] Seidel et al.[15] earlier reported body circumference measurement as an easy method of predicting intra-abdominal and subcutaneous fat. The results of this study justify the use of the inelastic tape measure in assessing body adiposity when BIA or skin fold calipers are not available. These results have implications for the assessment of body fat composition because utilizing the body circumference measurement technique with the readily available tape measure may make the assessment relatively cheap and less cumbersome in clinics.

The results of this study reveal that regardless of the method employed in estimating body adiposity, females have more percent body fat than males. This finding corroborates previous findings by Gallager et al.[16] and Yao et al.[17] which reported significantly higher percent body fat values for women than men as estimated from skin fold thickness and anthropometric measures. This is however not surprising because the biological composition of women (oestrogen and other female hormones) are precursors for increased fat deposition.

Table 3. Comparison of percent body fat score by measurement methods and BMI classification

BMI classification	PERCENT BODY FAT N (%)	STM Mean±SD	BCM Mean±SD	BIA Mean±SD	F- value	p- value
Underweight	40 (23.8%)	16.6±6.5	14.2±4.7	11.9±5.8	6.514	0.002
Desirable weight	84 (50.0%)	18.8±7.9	17.1±6.2	17.2±6.9	1.593	0.205
Overweight	26 (15.5%)	23.5±7.8	22.2±7.5	24.4±5.9	0.614	0.544
Obese	18 (10.7%)	31.9±5.3	33.3±6.2	33.3±4.6	0.377	0.688

P < 0.05

Key: STM: skinfold thickness measurement; BCM: body circumference measurement; BIA: bioelectrical impedance analysis

Table 4. Correlations of percent body fat scores from the three methods

Participants	N		STM	BCM	BIA
All subjects	168	STM			0.856*
		BCM	0.896*		
		BIA		0.906*	
Underweight	40	STM			0.742*
		BCM	0.848*		
		BIA		0.751*	
Desirable weight	84	STM			0.830*
		BCM	0.879*		
		BIA		0.844*	
Overweight	26	STM			0.810*
		BCM	0.872*		
		BIA		0.950*	
Obese	18	STM			0.914*
		BCM	0.834*		
		BIA		0.902*	

$p < 0.000$

Significant differences exist in percent body fat estimates between skin fold thickness and BIA in the underweight body category. Cursorily, this difference may suggest that BIA is less sensitive to body fat than the skin fold thickness measurement among underweight participants. However, this result equally suggests that body circumference measurement may be a more consistent measure of body fat among the underweight than either skin fold thickness or BIA, since no significant variance was found for it in the analysis. This finding is revealing when viewed in the context of the linear relationship that exists between underweight and malnutrition. Circumference measurements have been considered to provide better estimates of the nutritional status of individuals.[18]

Although, a strong correlation was found in the percent body fat composition among the three methods, the strongest relationship in percent body fat composition existed in the estimation between BIA and body circumference measurement. A similar correlation coefficient value had been reported for body fat measurement between BIA and body circumference measurement.[18] The significant positive correlation between skin fold thickness measurement and BIA is consistent with the finding of Aghdassi et al.[19] Similarly, Hedge and Ahuja[20] found a significant positive correlation between skin fold thickness measurements and body circumference measurements. When viewed from the context that BIA and skin fold calipers may not be readily available in most clinics in developing countries, Nigeria inclusive, the inelastic cloth tape measure as used in measuring body girth in this study may is proposed as an alternative for estimating body adiposity with as much accuracy as the skin fold calipers and the Omron BF-32 BIA device.

CONCLUSION

There is a strong correlation among the percent body fat of young adult Nigerians, estimated from body circumference measurement, skin fold thickness measurement and bioelectrical impedance analysis. These findings suggest that the non-elastic tape measure that is readily available and affordable can be used in assessing body adiposity clinically. However, the result of this study may be limited by the relatively small sample size and the homogeneity of the environment of the participants. Further study involving larger numbers of participants from several environments may be necessary for the generalization of this finding.

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