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Comparison of Three Prediction Equation of Body Fat Percentage via Skinfold Thickness Method with Segmental Multi-Frequency Bioimpedance in Caucasian Area Adolescent Boys

[1]A. Valizadeh, [1]M. Khorshidi Hosini, [1]M. Siahkohiyan, [2]A. Naghizadeh Baghi, [2]M.H. Dehghan and [1]L. Bolboli
[1]Department of Physical Education and Sport Sciences, University of Mohaghegh Ardebili, Iran
[2]Faculty of Medicine, Ardabil University of Medical Science, Ardabil, Iran

Abstract: Body composition is frequently used as one of several indicators of overall health fitness. Accurate measurements of the body composition in young boys are essential to evaluate nutritional status and health implications. This study was conducted to compare 3 equations Brozek , Slaghter and Jackson-pollock, in prediction of Body Fat percentage (%BF) via Skinfold thickness (SKF) method with Segmental Multi-Frequency Bioimpedance (SMFBIA) as a criterion method, in 15-17 years-old Azerbaijan-Iranian adolescent boys. Subjects were 45 healthy boys whose mean±SD age, height, weight and BMI were 16.04±0.767 years, 168±7.73 cm, 59.6±9.77 kg, 20.69±3.19 kg m^{-2}, respectively. %BF values were calculated using three selected equation and SMFBIA (inbody 3). Methodological differences among the these methods (three selected equation and BIA) were analyzed with Bland-Altman (1986) method. The value mean±SD of %BF were obtained using the SMFBIA method (12.45±6.15%). Results showed that predicted %BF by brozek-lohman equation has highest agreement with SMFBIA method (mean±SD difference,(-0.99±1.25%, $p<0.05$). Slaghter equation overestimated %BF comparison with SMFBIA (5%, $p<0.05$) and Jackson-pollock equation underestimated %BF comparing with SMFBIA (-5.46%, $p<0.05$). This study demonstrates that; although all equations used in present study have been commonly utilized to estimate body fat percentage in world adolescent boys, but the brozek-lohman equation hold promise for estimating (%BF) in Azerbaijan -Iranian adolescent boys. Obviously it is necessary to do further studies.

Key words: Body fat percentage, bioelectrical impedance multi-frequency**,** agreement, Caucasian adolescent boys

INTRODUCTION

Body composition is frequently used as one of several indicators of overall health fitness (De Lorenzo *et al*., 1996). Accurate measurements of the body composition in young boys are essential to evaluate nutritional status and health implications (De Lorenzo *et al*., 1998). Providing fundamental whole-body descriptive characteristics, accurate measures of body composition often are required as scaling factors to normalized physiological variables (Goran, 1998). The lack of direct methods has led to development of various models and indirect methods for estimating of fat and fat free mass, all of which are imperfect and require a number of assumptions, many of which require age-specific consideration, because the usual assumptions multi compartmental models are known to be influenced by age and state of maturity (Goran,1998). Skinfold thickness measurement is widely used as a indirect technique for assessment of body composition (De Lorenzo *et al*., 1998) because this would allow quick determination of body composition without needing for specialized laboratories, radiation exposure or expensive equipment (Dezenberg *et al*., 1999). Many skinfolds have been developed to predict body fat percent and fat mass from simple anthropometric parameters. The testing of anthropometric prediction equations in independent groups is of particular importance for several reasons: First, although there are standardized methods in measurement of skinfolds by nature is sensitive to inter user variability. Second, because of potential gender-ethnic- and maturation-related changes in body composition, the relationship between skinfold measures and body fat may vary between subgroups of the population (Goran, 1998). For example, Body composition studies of non-Caucasian ethnic groups have never equaled the application to

Corresponding Author: A. Naghizadeh Baghi, Faculty of Medicine, Ardabil University of Medical Science, Ardabil, Iran

samples from Caucasians (Cameron and Shumei, 1997). Thus, it is important to identify anthropometric measures that are robust to inter user variability and equally reflective of body composition in all subgroups of the population (Goran, 1998). One of the major limitations of comparing body composition techniques is the lack of a gold standard (De Lorenzo *et al*., 1998). Bioelectrical resistance is an alternative technique for assessing body composition in clinical and population-based studies (Goran, 1998). In addition a comprehensive evaluation through an examination (skinfold, ultrasound, sulfur hexafluoride and under water weighing) with respect to the validity, reliability, objectivity and practicability suggests that the bioelectrical impedance could be the best method to assess human body composition *in vivo* (Demura *et al*., 1999). In addition to this, segmental and multi-frequency features for BIA have been developed for increasing accuracy and may help to explain inter-individual variations in body composition more precisely than an impedance measurement at a single frequency can do (Jukka, 2003; Cameron and Shumei, 1997). When impedance data are collected at multiple frequencies, the amount of interpretable information per subject can be large, especially if numerous frequencies are measured (Cameron and Shumei, 1997). Multi-frequency capability of the BIA measurement has definitely brought some advance in accuracy of the assessment (Ellis *et al*., 1999). The purpose of study was, to compare three equations (Brozek, Slaughter and Jackson-pollock) in prediction of body fat percentage via Skinfold thickness (SKF) method with Segmental Multi-Frequency Bioimpedance (SMFBIA) as a criterion method, in 15-17 year-old Azerbaijan-Iranian (Caucasian area) adolescent boys. Therefore, we first measured the %BF using SMFBIA and selected equation. Then analyzed the agreement between the SMFBIA %BF and the %BF derived from SKF equations in subjects.

MATERIALS AND METHODS

Participants: Forty five boys high school student, age 15-17 years who randomly sampled from urmia collages, were took part in the study. The adolescent characteristics of individuals are presented in the Table 1. Prior to participating, volunteers read and signed an information consent document and completed a physical activity and health readiness questionnaire.

Measurements: The measurements was performed by a M.S and Ph.D exercise physiologist in laboratory of Urmia university physiology studies center (43% humidity with a temperature of 25°C). Their height and body weight were measured to the nearest 0.1 cm and 0.1 kg using electronic height and weight scale. The mean values of 2 measurements were used for data analysis. Segmental Multi-Frequency Bioimpedance (SMFBIA) (Inbody 3.0, Biospace Co., Seoul, Korea) measurements were carried out according to general recommendations. The measurements were performed after 12 h fasting and within 30 min of voiding the urinary bladder. No physical exercise was allowed before 4 h of the measurement (National Institutes of Health, 1996a, b). The equipment involves placing eight tactile electrodes on a subjects in an upright posture. When the subject was standing on the sole electrodes and gripping the hand electrodes, the microprocessor was switched on and the impedance analyzer started to measure the segmental resistances of the right arm, left arm, trunk, right leg and left leg at for frequencies (5, 50, 250 and 500 KHz), thus measuring a set of 20 segmental resistances for one individual. The mean values of 2 sets of SMFBIA measurements were used for analysis. The procedure was performed in 3 min or less and the SMFBIA %BF was automatically calculated from the BIA with equations installed in the instruments program (Cha *et al*., 1995). We chose the Brozek, Slaughter and Jackson-pollok formulas prediction of body fat percentage via Skinfold thickness (SKF) method. Skinfold measures were performed by grasping the subcutaneous adipose tissue at selected sites (equation) on the right side of the body using Lafayet Skinfold Calipers (USA).

Existing prediction Eq. 1. Brozek. Brozek derived prediction equations for body fat percent (%BF) based on body density from under water weighting. In this study body density was estimated using the Lohman equation. The equations are as fallows:

$$BD = [1.0982 - (\Sigma SF * 0.000815)] + [(\Sigma SF)^2 * 0.00000084]$$

ΣSF = The sum of the triceps, subscapular and abdomen skinfold measurements

$$\%BF = [(4.57 / BD) - 4.142] * 100$$

Existing prediction Eq. 2. Slaughter derived prediction equations for body fat percent (%BF) based on body density from under water weighting, in 310 subjects aged 8-29 years. The equations are as fallows:

$$\%BF = 1.021 * (\text{triceps} + \text{subscapular}) - 0.008 * (\text{triceps} + \text{subscapular})^2 - 1.7$$

If the sum of the triceps and subscapular measurements are > 35, however, the fallowing equations are suggested:

$$\%BF = 0.783 * (\text{triceps} + \text{subscapular}) + 1.6$$

Existing prediction Eq. 3. Jackson- Pollock derived prediction equations for body fat percent (%BF) based on body density from under water weighting. In this study body density was estimated using the Jackson- Pollock equation. The equations are as fallows:

BD = 1.1093800-0.0008267 (ΣSF) + 0.0000016 (ΣSF)^2 – 0.0002574 (age)

ΣSF = The sum of the pectolaris, femur and abdomen skinfold measurements

Where age in years

$$\% BF = [(5.03 / BD) - 4.59] * 100$$

Statistical analyses: Bland-Altman analysis was used to compare methods against each other (Bland and Altman,1986). Bland-Altman analysis is a statistical method where compares a mean difference against average values from two different methods (differences between %BFs for each subject were plotted against each subjects mean %BF of the same two methods to explore any difference in agreement between measurement methods). The solid line on each plot represents the mean of differences and the variations between methods are then presented as a ±2SD, which represents 95% limit of agreement (the dashed lines). The data were analyzed using MedCalc software, version 8.2.1.0. The level of statistical significance was set at a probability of $p<0.05$ for all tests.

RESULTS

The physical characteristics of the subjects are presented in Table 1. The mean %BF values from SMFBIA and skinfold thickness method (three selected equation) with SD, minimal, maximal and range values are presented in Table 2. Bland-Altman analysis was calculated as a mean difference against average values with ±2SD for %BF between SMFBIA and three equations Brozek, Slaughter and Jackson-pollock) prediction of SKF method. The values are presented in Table 3 and plotted in (Fig. 1a-c). The results of Bland-Altman analysis showed that predicted %BF by Brozek-Lohman equation

Table 1: Physical characteristics of subjects (N = 45)

Variable	Mean±SD	Range
Age (yr)	16.04±.77	15 - 17
Height (cm)	168.06±7.73	157-184
Weight (kg)	59.6±9.77	42.6-85.5
BMI(kg m^{-2})	20.7±3.18	17.3-28.2

Table 2: The mean, SD, minimal, maximal and range values %BF values from BIA multi-frequency and SKF method (three selected equation) of subjects

Method	Range	Min	Max	Mean	SD
BIA	27.8	5.8	33.6	12.54	6.1
Brozek	24.4	6.5	30.9	11.46	5.4
Jackson	19.5	1.4	20.9	6.99	5.3
Slaughter	32.5	7.5	40	17.45	7.4

Table 3: Statistical analysis data comparing SKF (three selected equation) to BIA multi-frequency method

Method	Mean diff	95%CI Mean diff	SD diff	Upper limits	Lower limits
BIA- Brozek	-0.98	-0.6 to -1.36	1.25	1.46	-3.44
BIA- Jackson	-5.46	-4.5 to -6.41	3.17	0.76	-11.68
BIA- Slaughter	5	6 to 3.96	3.46	11.78	-1.8

All data based on %BF determined from methods

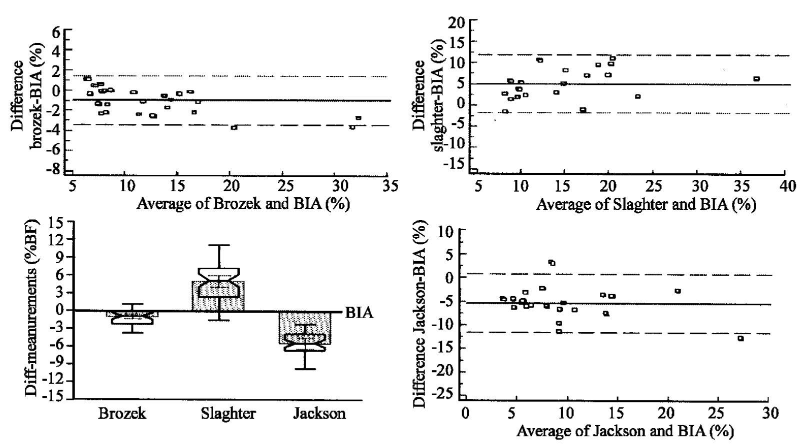

Fig. 1: Bland-Altman plots comparing BIA %BF against Brozek (A), slaughter (B) and Jackson (C) equations. The x-axis represents the mean of both BIA %BF and prediction SKF methods %BF for each subject; the y-axis represents the difference between BIA %BF and predicted SKF methods %BF for each subject. solid lines represents the mean of differences; dashed lines represents the upper and lower limits of agreement (mean diff ±2SD diff). Box-and-whisker plot comparing difference measurements of %BF in three selected equation against BIA (error bars: %95 CI for mean) (D)

has best agreement with SMFBIA method (narrowest margins between limits of agreement). whereas predicted %BF by Slaughter and Jackson-pollock equation has low agreement with SMFBIA method (wide margins) and over and underestimated %BF comparing with SMFBIA, respectively.

DISCUSSION

In present study, we evaluated three equations (Brozek, Slaughter and Jackson-pollock) SKF in 2-C model and estimated % F compared to SMFBIA. The Bland-Altman plots (Fig. 1a-c) describe the agreement (how close one measure compares to another) in %BF estimates between two body composition methods and it is suggested be more useful indication compared to r, r^2 and SEE as to whether one method can be a valid substitution for another (Diboll and Moffit, 2003).

The derived results of the presnt study implies that there is a considerable agreement between Brozek equation and SMFBIA (Table 3). Mean different value in 95% of agreement domain shows underestimation in %BF data obtained from Brozek-lohman equation (Fig. 1a). Similar results have been demonstrated earlier, for example Arroyo *et al.* (2004) reported same trend in results in comparison between Brozek equation with BIA single frequency (mean differences -1.4). Also Koda *et al.* (2000) and Utter *et al.* (2003) set study to compare body density estimation methods used Brozek equation to estimate %BF. A Brozek-lohman equation is also one of two reference methods that National Collegiate Athletic Association (NCAA) approves in estimating athlete %BF particularly for young wrestlers weight certification program (Diboll and Moffit, 2003). By considering all previous studies and present study it seems that Brozek equation that use Lohman body density equation to estimate %BF in adolescent is a reliable method in various population subgroups and conforms this study's results that has been done on Caucasian area population sub group.

By comparing data obtained from Slaughter equation for %BF estimation with data obtained from SMFBIA it seems that there is no agreement between these two methods (Table 3) and Slaughter equation overestimates %BF (Fig. 1b). About this issue Nicholson *et al.* (2001) compared Slaughter equation with ADP method and reported Slaughter equation underestimates girls %BF (-3.7%) and overestimates boys %BF (2.4%). De Lorenzo (1998) and Dezenberg (1998) also compared Slaughter equation with DXA method on people with different age groups and reported contradictory results, while Lorenzo believes the Slaughter equation is appropriate method to estimate %BF for adolescents. Dezenberg has declared in his study's that Slaughter equation underestimates %BF in people with average or low adipose tissue and overestimate %BF in subjects with high adipose tissue (Dezenberg *et al.*, 1999; De Loranzo *et al.*, 1996). In another study Janz *et al.* (1993) compared Slaughter equation with Lohman-Siri equation as a criterion method and declared that Slaughter equation can help to estimate %BF in adolescents but they didn't choose reliable procedure so they proposed that slaughter equation should be revised by using other reliable methods on various population (Janz *et al.*, 1993). To explain contradictory results obtained of many studies two factors have been mentioned firstly different kinds of ethnic subgroups have been studied in previous studies, secondly Slaughter equation studied cases consisted of wide range of age groups like children, young adolescents and mature adolescents and differences in results might have been caused by this factor.

This study's result by considering SD and mean differences value shows Jackson-pollock %BF estimation equation and SMFBIA don't have quit agreement and Jackson-pollock equation underestimates %BF compared with SMFBIA (Fig. 1c). About this fact Fogelholm and Lichtenbelt (1997) meta analysis result that has been obtain of studying 54 papers published since 1985 until 1997 about comparing Jackson-pollock equation with other methods shows Jackson-pollock equation underestimates %BF for Caucasian population. Also Peterson have done study in USA to compare Jackson-pollock equation with a 4- compartment model of body composition that shows Jackson-pollock equation underestimates %BF (Peterson *et al.*, 2001). A large number of studies in various population subgroups have been done and results are almost similar to each other and have agreement with this study's result. To explain Jackson-pollock equation %BF underestimation in comparison to more reliable and precise methods to measure body composition in many studies it could be said that while Jackson-pollock equation was developed there wasn't any perfect procedure to analyze It's validity and now days by modern body composition assessment methods It's underestimation has been revealed.

CONCLUSION

In summary, we were not able to cross-validate the equation of slaughter and Jackson-pollock in sub group of Caucasian adolescents. This study demonstrates that Although the all equations used in the present study have been commonly utilized to estimate body fat percentage in world adolescent boys, but the Brozek equation by using body density data obtained of Lohman equation hold promise for estimating (%BF) in Azerbaijan-Iranian adolescent boys. Obviously it is necessary to do further studies.

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