Comparison of Different Measurement Equations for Body Composition Estimation in Male Athletes

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Abstract

The purpose of this study was to compare the validity between three established prediction equations and our prediction equation referenced by DEXA (Dual-energy X-ray absorptiometry) on fat free mass (FFM) in Taiwan male soccer players. Methods: Twenty seven elite Taiwan soccer players were estimated by bioelectrical impedance analysis (BIA) and DEXA. The R2 value of FFM estimated by our prediction equation and DEXA was 0.918. The R2 values of FFM estimated by three different stablished prediction equations and DEXA were 0.725, 0.794 and 0.868, respectively. In summary, our specialized prediction equation shown the highest correlation among equations suggestion evaluating athletic body composition should use appropriate prediction equation rather than that of for general people.

Keywords: Bioelectrical impedance analysis (BIA), Dual-energy X ray absorptiometry (DEXA), Free fat mass (FFM)

Introduction

Body composition, can be determined using several measurements such as body mass index (BMI), skinfold thickness, and body circumference; however, these measurements have limited usage. Many laboratory-based methods to estimate body composition also exist, but only a few of these methods provide rapid, easy, and effective estimation of body composition. Bioelectrical impedance analysis (BIA) is based on Ohm's law and the principles of voltammetry. BIA is commonly used to estimate fat-free mass (FFM), body fat (BF), body cell mass (BCM) [1], and total body water (TBW) [2] in patients and healthy subjects. However, many parameters such as height, weight, gender, race, and age [3-4] affect the accuracy of the prediction equation in BIA, particularly, in special classes of individuals such as athletes. Therefore, a prediction equation for the accurate estimation of body composition in athletes needs to be developed.

Dual-energy X-ray absorptiometry (DEXA) is currently used as the gold reference method for the measurement of body composition [5-6]. Some studies have shown that precision and accuracy of DEXA on body composition estimation were higher than that of BIA [7-8]. A derived prediction equation to determine FFM, fat mass and percentage BF referenced with DEXA, the foot-to-foot BIA was an accurate technique in the measurement of body composition better than anthropometric indices in children [9]. In contrast, some studies have reported that both BIA and DEXA are equally accurate [10-11].

Among athletes, physical parameters such as body composition differ depending on the type of sport, the level of competition, and athletic performance. For example, it has been reported that swimmer tend to have higher BF than jogger. A higher FFM was required for increased power and strength; therefore, low BF percentage was commonly observed in athletes [12-13].

There may be an intrinsic bias in the use of impedance in athletes because of a generally lower BF percentage in athletes than in the normal population such that fatness tends to be overestimated at the lower end of BF values [14]. As a general rule, there are larger regression artifact on extreme leanness or obesity ends of regression curve, whereas at the extreme of obesity predictive equations tend to underestimate fatness. Several investigators have developed equations to estimate only the body composition for the obese and lean extremes of the BF spectrum. However, values may get interchanged because the range of body composition values is extremely limited within a homogeneous group of athletes.

In this study, to develop specific prediction equations for

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Taiwan athletes, we conducted a new prediction equation from the BIA value of Taiwan male soccer players.

Methods

Subjects

This study included 27 male elite athletes aged 18–26 years who have been playing soccer over 7 years. The measurements were taken during the offseason when the subjects were not training. However, they performed aerobic exercise for 15 hours a week, and heart rate was 160 beats per minute. The physical characteristics of the subjects are shown in table 1.Height and weight were measured by anthropometric measurement. Body composition were determined by both BIA and DEXA. The study was approved by the Institutional Review Board Advisory Committee at Jen-Ai Hospital in Taiwan and adhered to local ethics guidelines. The purpose, methods, procedures, steps, and any safety-related issues concerning the study were explained to the subjects. All subjects provided their informed consent for participating in this study.

Anthropometry and BIA

In this study, an 8-electrode bioelectrical impedance analyzer (Tanita BC-418; Tanita Corp., Tokyo, Japan) was used to measure FFM. The FFM and BF measured by DEXA (Lunar Prodigy; GE Corp., USA) at 20 μGy with the enCore 2003 software (Version 7.0) by an expert operator of the Department of Radiology, Dah Li County, Jen-Ai Hospital in Taiwan. All measurements were conducted in the morning under fasting conditions and at least 12 h after exercise.

Table 1. Physical characteristics of male atheletics

	Male (N=27)	
	Mean ± SD	Range
Anthropometric		
Age (yr)	20.43 ± 1.87	17.80 -026.40
height (cm)	174.34 ± 5.39	160.00 -181.00
weight (kg)	66.78 ± 5.31	55.00 - 75.90
Body mass index(kg/m^2)	21.86 ± 1.08	19.59 - 24.80
Bioelectrical impedance		
Resistance (Ohms)	542.77 ± 42.74	477.79 - 639.42
Reactance (Ohms)	82.55 ± 6.71	72.80 - 96.50
Z score (Ohms)	549.03 ± 43.01	484.00 - 646.00
Fat-free mass (FFM, kg)	58.18 ± 5.18	48.24 - 067.61
Fat mass (kg)	6.46 ± 2.14	3.59 - 12.42
Fat mass (%)	9.51 ± 3.00	5.10 - 16.60

Statistics analysis

All of the experimental data were analyzed by the SPSS.14.0 software (SPSS Inc., Chicago, IL, USA). Results were represented as mean and SD. A confidence level at 5% ($p < 0.05$) was considered significant. A new predictive equation was conducted by linear regression analysis. Correlations between equations and DEXA variables was determined by Pearson correlation coefficient. Differences of fat free mass between predictive equations and DEXA were analyzed by Bias.

Results

Predictive equation of FFM in Taiwan male athletes

A new prediction equation including four parameters, height, weight, resistance, and age, with the variables of 27 Taiwan male athletes was developed by regression as equation (1a).

FFM (kg) = $-2.215 + 0.185\ h^2/Z + 0.778\ w - 0.072\ y$ (R^2 = 0.918, SD = 1.96 kg)..............................(1a)

FFM: fat free mass (kg)
h: body height (m)
Z: bioelectrical impedance (ohm)
w: body weight (kg)
y: age (years)

Another prediction equation including three parameters, height, weight, and resistance, with the variables of 27 Taiwan male athletes was developed as equation (1b)

FFM (kg) = $-3.617 + 0.171\ h^2/Z + 0.786\ w$, ($R^2$ = 0.924, SD.= 1.98 kg)............................(1b)

Comparison of the FFM values determined from the equations and the DEXA measurements

In present study, compared to previous three body composition estimates equation to estimate FFM. The correlation (R^2 value) of FFM estimated by our prediction equation and DEXA was 0.918. The R^2 values of FFM estimated by three different established prediction equations (Table 2 and Figure 1) and DEXA were 0.725 for Lohman''s [17], 0.794 for Steward's [18] and 0.868 for Steward's [18], respectively (Table 3).

Mean differences of FFM between predictive equations and DEXA

The mean difference (Bias) of FFM estimated by our prediction equation and DEXA was zero. Mean differences of FFM estimated by three different established prediction equations and DEXA were -4.93 for Lohman's [17], -3.50 for Steward's [18] and 8.65 for Steward's [18], respectively (Table 3 and Figure 2)

Table 2. Published formulas for calculating fat-free mass in male with bioelectrical impedance analyzer

Name	Formulas
Lukaski & Bolonchuk. 1987, [16]	$FFM = 0.734Ht^2/R + 0.116m + 0.096Xc - 3.152$
Lohman et al, 1992, [17]	$FFM = 0.485Ht^2/R + 0.338\ m + 5.32$
Stewart et al, 2000, [18]	$FFM = 294.3Ht^2/R + 662.70\ m + 71.8 \cdot Xc + 662.7$

FFM,fat-free mass in kilograms; m,total body mass in kilograms; Ht, height in centimetres; R,resistance in ohms and Xc is reactance in ohms.

Table 3. Biases (mean difference) and correlation coefficients of fat-free mass between predictive equations and DEXA

	FFM				
BIA	R^2	slope	Interrupt	Bias	SD
male(n=27)					
Kao et al.	0.918*	0.805	13.68	0.(	1.96
Lukaski & Bolonchuk. 1987, [16]	0.725*	0.628	16.66	-4.9:	2.78
Lohman et al, 1992, [17]	0.794*	0.693	14.32	-3.5(	2.43
Stewart et al, 2000, [18]	0.868*	0.795	20.53	8.6.	1.92

Note：* $P< .05$

	FFM				
BIA	slope	Interrupt	SD	R^2	Bias
male(n=27)					
Kao et al.	0.805	13.68	1.96	0.918*	0.0
Lukaski & Bolonchuk. 1987, [16]	0.628	16.66	2.78	0.725*	-4.93
Lohman et al, 1992, [17]	0.693	14.32	2.43	0.794*	-3.50
Stewart et al, 2000, [18]	0.795	20.53	1.92	0.868*	8.65

Note：* $P< .05$

Discussion

In the present study, we compared the validity of 3 established equations to that of our developed equation on FFM evaluation with the variables of 27 Taiwan elite male soccer players. Three established equations were conducted by Lukaski & Bolonchuk. [16], Lohman et al. [17], Stewart et al. [18] and were derived from general people. Three above established equations for FFM estimation were validated by comparison with the results of multi-compartment model [19-20], densitometry (underwater weighing) [21], DEXA [22], isotope dilution, and total body potassium (TBK) [21-22] measurements. Except DEXA, above reference methods have limitations and require some assumptions and, thus, they are not applicable in all situations. Our predictive equation was derived from Taiwan elite male soccer players and referenced with DEXA gold standard.

The results calculated from the 3 established equations with the variables of 27 Taiwan elite male soccer players were compared to the results obtained from DEXA measurements. After regression analysis, correlations were obtained between the results obtained by DEXA and three equations (the range

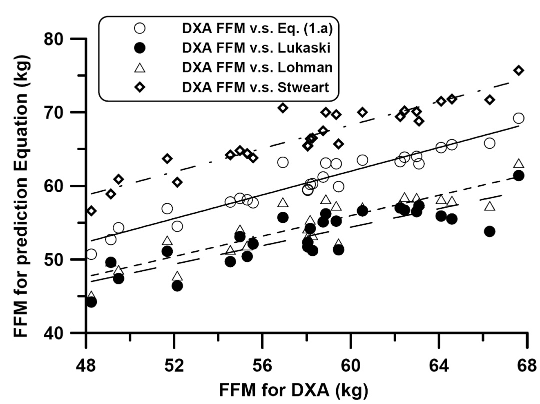

Figure 1.The relationship between predictive equations and DEXA on fat free mass.

of R^2 were from 0.725 to 0.868, table 3). However, the correlation (R^2 value) of FFM estimated between our (1a) prediction equation and DEXA was 0.918. The R^2 value of

FFM estimated between our (1b) prediction equation and DEXA was 0.924. Both of the validities of our predictive equations were better than that of three established equations. Moreover, it was showed that an additional age parameter on equation (1a) than on equation (1b) could not increase the validity. It is possible that the range of subjects' age was so narrow as to the age was not a factor on our predictive equations.

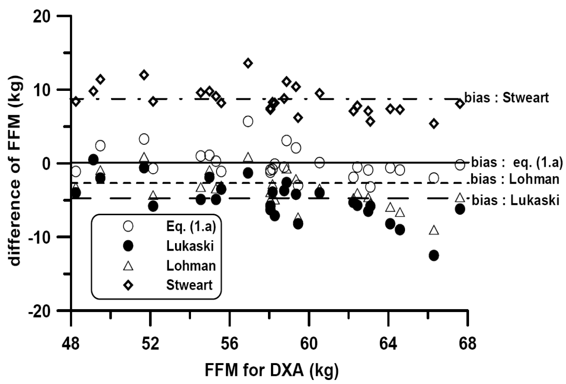

Figure 2. Differences of fat free mass between predictive equations and DEXA.

The mean difference of FFM estimated by our prediction equation and DEXA was zero (Figure 2). Mean differences of FFM estimated by three different established prediction equations and DEXA were -4.93 for Lohman''s [17], -3.50 for Steward's [18] and 8.65 for Steward's [18], respectively. It showed that our predictive equations have the best validity among all equations by evaluated with their mean differences. Most established prediction equations on FFM estimation were derived from general people. Athlete population is just a small part in parent population. Using prediction equation of whole population range to predict small population range was not thorough and will lead to precarious. In this study, our specialized prediction equation for athlete shown the highest correlation among equations suggested evaluating athletic body composition should use appropriate prediction equation rather than that of for general people.

Further research is necessary to validate the applicability of BIA prediction formulae in other athletic populations.

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