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COMPARATIVE ASSESSMENT OF SELECTED BODY COMPONENTS FROM BIOELECTRICAL IMPEDANCE OR SKINFOLD MEASUREMENTS

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Body composition was assessed by two methods: from 3 skinfolds (SF; brachial, pectoral and crural), and by bioelectrical impedance (BIA). The absolute and relative values of body fat content and of lean body mass (LBM) were determined in 110 healthy men aged 22.1±1.2 years; their body mass index (BMI) was 22.7±1.9 kg·m^{-2}. In no case the regression equations differed significantly from identity lines. The computed total errors were equal to 1.18 kg or 1.61% for body fat and 1.26 kg or 1.70% for LBM. Both methods can thus be used interchangeably. ***(Biol.Sport 15:205-212, 1998)***

Key words: Body composition - Skinfolds - Bioelectrical impedance

Introduction

The assessment of proportions between body components is of great importance e.g. in sports, particularly those involving weight categories. It is also useful in recreational activities for the purpose of monitoring the effects of training on body composition. The only factor which limits such monitoring is the practical availability of a fast and reliable measurement method.

The use of diverse methods of determining body components has been criticised because of non-uniformity of results they render [1,3,13,15]. The most modern methods employ computer tomography, dual photon absorptiometry, or nuclear magnetic resonance. These methods, however, cannot be used in routine determinations due to high costs and sophisticated equipment.

In recent years, a method based on bioelectrical impedance (BIA) has been introduced [16,22]. That non-invasive method is fast and reliable and may be applied to athletes, also under field conditions. It has been widely used in medical research [1,2,11,17,28]. The increasing popularity if BIA implies the necessity of comparing the results obtained by that method with those obtained by skinfold measurements and this constituted the aim of the present study.

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Material and Methods

Measurements of body composition by bioelectrical impedance (BIA) and by skinfold thickness (SF) were conducted in 110 healthy men aged 22.1±1.2 years. Their mean characteristics and results of measurements are presented in Table 1. All measurements were conducted in the morning. The subjects were informed about the aim of the study.

Bioelectrical impedance measurements (BIA): A computerised BIA analyser and software Weight Manager 2A (RJL System Inc., USA) were used. The measurements were conducted on the subject in supine position with arms pronated by the side of the body. Two electrodes measuring the resistance were placed in the midpoint of the 3rd metacarpal bone and two other ones in the midpoint of the 2nd and 3rd metatarsal bones. Duplicate measurements were performed, mean values being used for determining lean body mass (LBM), fat, water content, body mass index (BMI) and LBM-fat ratio.

Skinfold measurements (SF): Three skinfolds were measured: brachial (over the triceps, at the midpoint of the arm; X_2), pectoral (at the level of the 10th rib; X_3) and crural (slightly outwards from the popliteal fossa; X_4). The measurements were performed with Harpenden's caliper on the left side of the body. From these values, body density was computed according to the formula $D=1.124 - 0.00012 \cdot \log X_2 - 0.000167 \cdot \log X_3 - 0.000075 \cdot \log X_4$. This, in turn, served to compute the percentage of body fat and lean body mass [19].

Data analysis: The distributions of all variables proved normal by Shapiro-Wilk's test. For all data, means (±SD) and coefficients of variability (CV) were computed as well as regressions of BIA vs. the SF data. Moreover, for each comparison the total error was computed, i.e. the mean square difference between the corresponding values (BIA - SF). The level of $P \leq 0.05$ was considered significant.

Results

Mean values (±SD and CV) of all variables studied are presented in Table 1. The group studied was rather uniform regarding body height and mass; more-over, about 96% of subjects could be classified as having normal body fat content, i.e. between 10 and 18%. A slightly but consistently higher variability of results was observed for the BIA method, compared with the SF measurements. Mean BIA results of fat content were slightly but highly significantly higher than in case of the SF method and corresponding opposite changes were noted for LBM.

The regression equations comparing the results obtained by both methods are presented in Table 2. In no case the slope differed significantly from unity or the intercept from zero. Therefore, individual results were plotted (Figs. 1 and 2) and identity lines ($y=x$) were chosen as regressions. Accordingly, the errors of the method were expressed as the so-called total errors (TE) and presented in Table 2 together with the standard deviations in the computed regressions ("residual errors"). The total error for the relative fat content is 1.61%, irrespectively of the method applied, i.e. SF or BIA. Since the body mass index (BMI) is widely used and frequently regarded as reflecting the body fat content, its values were correlated with those of fat determined by both methods - BIA and SF. The coefficients of correlation were equal to 0.48 and 0.50, respectively.

Table 1
Mean values (±SD and percent coefficients of variability) of body components as determined by skinfold measurements (SF) and bioelectrical impedance (BIA)

Variable Method	Skinfold (SF) [19]	BIA
Age (years)	22.1±1.2 (5%)	
Body height (cm)	178.4±7.1 (4%)	
Body mass (kg)	72.3±8.5 (12%)	
Body mass index (BMI; kg $\cdot m^{-2}$)	22.7±1.9 (8%)	
Body density (g $\cdot cm^{-3}$)	1.062±0.008 (8%)	–
Resistance (Ω)	–	463±50 (11%)
Reactance (Ω)	–	57.3±5.7 (10%)
Body fat content (BF; kg)	10.3±2.4 (23%)	9.8±2.6 (27%)*
Relative body fat content (%)	14.3±3.2 (22%)	13.6±3.5 (26%)*
Lean body mass (LBM; kg)	62.0±7.7 (12%)	62.5±8.0 (13%)*
Relative lean body mass (%)	85.7±3.4 (4%)	86.3±3.5 (4%)*
LBM/BF ratio	6.44±1.77 (27%)	6.87±1.94 (28%)
Body water content (kg)	–	46.1±5.9 (13%)
Relative body water content (%)	–	63.6±3.1 (5%)

* Significantly different from the respective SF value ($P<0.001$)

Table 2
Computed regression coefficients (±errors) of absolute or relative values of body fat content or lean body mass (LBM) determined by bioelectrical impedance (BIA) vs. skinfold measurements (SF), as well as residual (from computed regressions) and total errors

Variables	Intercept	Slope	Residual error	Total error
Body fat (kg) BIA vs. SF	-0.462±0.456	0.994±0.043	1.06 kg	1.18 kg
Body fat (%) BIA vs. SF	-0.852±0.643	1.009±0.044	1.44%	1.61%
LBM (kg) BIA vs. SF	-0.31±0.87	1.014±0.014	1.13 kg	1.26 kg
LBM (%) BIA vs. SF	-0.04±4.01	1.009±0.047	1.53%	1.70%

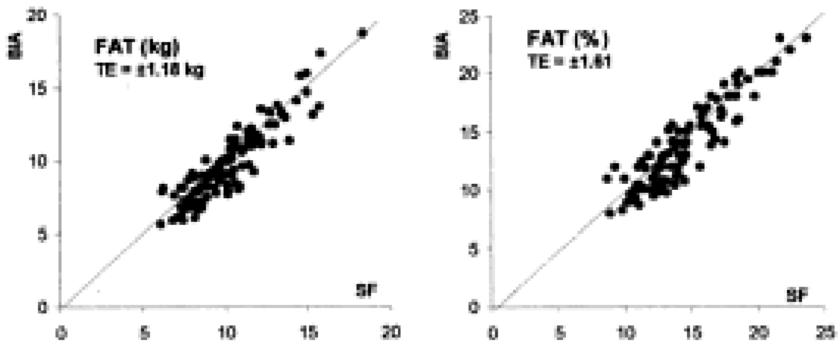

Fig. 1
Individual values of absolute (left) and relative (right) fat content determined by bioelectrical impedance (BIA) or from 3 skinfolds (SF). The identity line serves as regression.

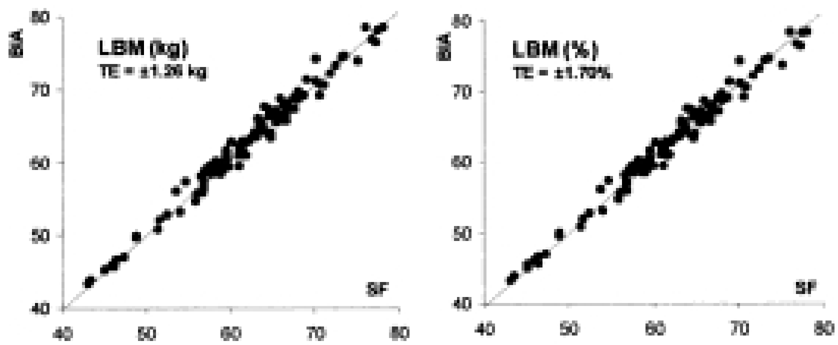

Fig. 2
Individual values of absolute (left) and relative (right) lean body mass (LBM) determined by bioelectrical impedance (BIA) or from 3 skinfolds (SF). The identity line serves as regression.

Discussion

In this study, a good agreement between the results obtained by two methods - bioelectrical impedance (BIA) and skinfold measurements (SF) has been demonstrated. The errors, both in absolute or relative units, are small enough to enable using both methods interchangeably. Similar results of comparing both methods were also reported by Lohman [16]. On the other hand, Kaminsky *et al.* [12] found significantly higher values obtained by the SF than by BIA method, the difference being as high as over 20%, although the results were well correlated with each other (r = 0.88). They found a much better average agreement between BIA results and those determined hydrometrically but individual differences were quite high (r = 0.50). Very high correlations between BIA and SF methods were reported by Jackson *et al.* [11] for lean body mass (r = 0.924) and by Jürimäe and Jüriso [10] for body fat (r ranging from 0.87 to 0.97). Those authors have not, however, presented regression equations.

In many studies on the assessment of body composition by various methods, the correlations between BIA and SF results ranged from 0.71 to 0.86. However, in groups where the range of body fat percentage was large, e.g. 3 - 28%, the correlations were lower than when differences in body fat content were smaller [7,8,10,18,21]. Similar observations were also made by Riu *et al.* [20] who studied subjects highly differing in their BMI, from below 17 to over 30 kg $\cdot m^{-2}$.

The slightly albeit significantly higher results of fat content obtained by the skinfold method in this study, compared with BIA results, may have resulted from e.g. uneven distribution of adipose tissue, variability in body water content and in skin elasticity. In case of BIA measurements, standardisation of the procedure, e.g. electrode positioning, body position, defatting of the skin, etc., plays an important role [4,24,25].

Bioelectrical impedance measurements proved reliable and highly useful also in children [4,5,21], or in adults in a 3 year-interval. That method may, however, produce questionable results in subjects keeping to very low-calorie diets [11].

The differences in body fat content determined by BIA or from skinfolds, may result from the fact that the bioelectrical impedance method measures total body fat while skinfold measurements are associated with the subcutaneous adipose tissue only. Nevertheless, the high consistency of results obtained by both methods makes them useful in determining body composition.

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