HUMAN MOVEMENT
2012, vol. 13 (2), 127–131

A COMPARATIVE ANALYSIS OF THE ANTHROPOMETRIC METHOD AND BIOELECTRICAL IMPEDANCE ANALYSIS ON CHANGES IN BODY COMPOSITION OF FEMALE VOLLEYBALL PLAYERS DURING THE 2010/2011 SEASON

doi: 10.2478/v10038-012-0013-6

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ABSTRACT
Purpose. The aim of this study was to observe the changes in body composition by using two measurement methods – anthropometric analysis and bioelectrical impedance analysis (BIA) – on a group female volleyball players and to compare the results of both methods. **Methods.** Eleven female volleyball players participated in this study during the 2010/2011 season. Measurements of body composition were performed with an electronic body composition analyzer (BIA method) adjusted for STANDARD physical activity levels and then using the anthropometric method as per Piechaczek's formula. Total lean body mass (LBM), total body fat content (FAT) and body water content were measured. Measurements were taken before preseason training (Measurement 0), one week before the end of preseason training (Measurement 1), after the first (Measurement 2) and the second (Measurement 3) half of the competitive season and four weeks after the seasons' playoffs during the offseason (Measurement 4). Additionally, during Measurement 4, body composition measured by the BIA method was adjusted for ATHLETIC physical activity levels. **Results.** Body mass, lean body mass and body water content did not change throughout the analyzed period. Body fat mass, as determined by $BIA_{STANDARD}$, increased from 20.7 ± 5.3 kg (Measurement 0) to 22.2 ± 5.0 kg (Measurement 1) but subsequently decreased to 21.2 ± 5.7 kg (Measurement 2) and remained at this level until the end of the competitive season. In the case of body fat as measured by the anthropometric method, a significant increase in fat was observed from 18.4 ± 3.0 kg to 19.3 ± 3.4 kg and then from 19.5 ± 3.5 kg to 19.8 ± 3.6 kg. Analysis of LBM and FAT values found significant differences between the values obtained using the BIA method at the ATHLETIC physical activity level and the results registered at the STANDARD level and those recorded by use of the anthropometric method. **Conclusions.** The results obtained using the BIA method set at the STANDARD mode of physical activity and those by the anthropometric method did not significantly differ. Significant correlation between the values obtained by the BIA method and anthropometric method was found.

Key words: body composition, anthropometric method, bioelectrical impedance, female volleyball players

Introduction

Assessing an individual's body composition is particularly important especially in the case of athletes who participate in sports that use weight categories (such as wrestling, judo) [1]. In addition, such an assessment is used to directly monitor the effects of physical activity and/or nutrition (diet) on body composition. Body composition is an important factor of physical fitness for volleyball teams, as excess body fat acts as ballast against the body's ability to perform a number of movements, such as the vertical jump. However, most athletes have their body composition measured only once [2–4]. Rarely is this important tool used to monitor an athlete throughout an entire competitive or training season [5].

In addition, the various methods used to assess body composition have themselves raised controversy and debate. Studies carried out by various authors using different measurement methods have pointed to significant differences in the attained values of body composition [6, 7]. Currently, the most popular method for determining body composition is through bioelectrical impedance analysis (BIA), which is considered to be simple, quick and noninvasive. Many authors [8–10] found a significant correlation between body composition measured by BIA and those by either anthropometric or hydrometric analysis. However, most of these studies were conducted on individuals who were not physically active or on students of physical education universities [10]. In addition, of those studies that attempted to tackle this issue, few were conducted on athletes, particularly female athletes [11, 12].

Therefore, the aim of this study was to observe the changes of body composition by using two measurement methods, the anthropometric method as well as bioelectrical impedance analysis, on a group of female volleyball players during the 2010/2011 season and to compare the results of both methods.

Material and methods

After receiving approval by the Senate Ethics Committee for Scientific Research of the Józef Piłsudski University of Physical Education in Warsaw, eleven Second Division volleyball players from the AZS AWF Warszawa sports club were selected to participate in the study. The physical characteristics of the subjects (N = 11) were: age 21.6 ± 1.7 years, height 177.9 ± 4.6 cm,

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body mass 71.3 ± 6.6 kg, career length 8.6 ± 3.3 years. The participants were informed about the purpose and nature of the study and the possibility of withdrawing at any moment in time. Written informed consent was provided by all the participants prior to the experiment.

Measurements of body composition were carried out using a Model TBF-300 body composition analyzer (Tanita, Japan), set at the STANDARD setting for the level of physical activity. Body composition by use of the anthropometric method [13] was performed with three skinfold measurements on the arm, abdomen and below the shoulder with a caliper (SiberHegner, Switzerland). Body composition was then estimated by use of Piechaczka's method [14]. Total lean body mass (kg), total body fat (kg), total body fat content (%, kg) and total body water content (kg) were then calculated. Body height, weight and skinfold thickness were measured with an accuracy of 0.01 m, 0.1 kg and 0.001 m, respectively.

Generally, the total error of skinfold measurement does not exceed 6% [3], while the total error by measurement of body composition does not exceed 3% [15]. In this study, the maximum relative error of repeatability, expressed as an indicator of variability, for skinfold measurements ranged from 1.6% to 3.0% depending on the skinfold, while analysis of fat content by the BIA method (with two different available settings) was found to be for $BIA_{STANDARD}$ 0.3% and for $BIA_{ATHLETIC}$ 0.6%. The maximum relative error of repeatability was found to be consistent with the results of Kutáč and Gajda [16].

Measurements of body composition during the 2010/2011 season were taken before the start of preseason training (Measurement 0), one week before the end of preseason training (Measurement 1), after the first (Measurement 2) and the second (Measurement 3) half of the competitive season and four weeks after the seasons' playoffs during the offseason (Measurement 4). Additionally, during Measurement 4, body composition measured by the BIA method was adjusted for an ATHLETIC level physical activity (for individuals who intensively train for at least 10 hours a week and have a resting heart rate below 60 bpm). Throughout the entire study period the volleyball players did not have a special diet or modify their dietary intake.

In order to verify the obtained results of each of the measurements, one-way analysis of variance (ANOVA) with repeated measures was used, while ANOVA/MANOVA analysis was performed to compare the results of both of the measurement methods. The significance of differences among the obtained mean values was evaluated by Tukey's post-hoc test, with the relationships between the variables examined by use of Pearson's correlation coefficient. All statistical analysis considered a p value of < 0.05 to be significant. All calculations were performed using STATISTICA™ software (v. 9.0, StatSoft, USA).

Results

The obtained results (mean ± SD) are presented in Table 1. Body mass, body water content, lean body mass (LBM) were found to not significantly change during the period under analysis. Body fat mass (FAT), as determined by $BIA_{STANDARD}$, increased from 20.7 ± 5.3 kg (Measurement 0) to 22.2 ± 5.0 kg (Measurement 1) but subsequently decreased to 21.2 ± 5.7 kg (Measurement 2) and remained at this level until the end of the competitive season. Only the increase in FAT between Measurement 0 and Measurement 1 was found to be significant. In the case of body fat as measured by the anthropometric-Piechaczka's method (ANT), a significant increase in fat was observed between Measurement 0 and Measurements 2, 3 and 4. With the exception of Measurement 4, significant differences were observed between $BIA_{STANDARD}$ and the anthropometric method (ANT) in all of the measurements for FAT (%), FAT (kg) and LBM (kg).

The results of Measurement 4, taken by the BIA method at two different physical activity settings (BIASTA

Table 1. Changes in body tissue composition of the female volleyball players under study during the 2010/2011 season

Variables	Measurement 0	Measurement 1	Measurement 2	Measurement 3	Measurement 4
Mass (kg)	71.3 ± 6.6	72.3 ± 6.2	72.0 ± 6.9	71.2 ± 6.7	71.7 ± 6.8
BMI (kg/m^2)	22.5 ± 2.8	22.9 ± 2.8	22.8 ± 2.9	22.4 ± 2.7	22.6 ± 2.8
FAT_{BIA} (%)	28.7 ± 4.8	30.4 ± 4.3 [a]	29.0 ± 5.2	29.4 ± 4.6	29.7 ± 5.1
FAT_{BIA} (kg)	20.7 ± 5.3	22.2 ± 5.0 [a]	21.2 ± 5.7	21.2 ± 5.2	21.6 ± 5.6
LBM_{BIA} (kg)	50.6 ± 1.8	50.1 ± 2.0	50.8 ± 2.0	50.0 ± 2.0	50.1 ± 2.1
$Water_{BIA}$ (kg)	37.0 ± 1.3	36.7 ± 1.5	37.2 ± 1.4	36.6 ± 1.5	36.7 ± 1.6
FAT_{ANT} (%)	25.6 ± 1.9*	25.7 ± 2.4*	26.6 ± 2.4	27.2 ± 2.7 [ab*]	27.4 ± 2.7 [ab]
FAT_{ANT} (kg)	18.4 ± 3.0*	18.7 ± 3.3*	19.3 ± 3.4 [a*]	19.5 ± 3.5 [a*]	19.8 ± 3.6 [ab]
LBM_{ANT} (kg)	52.9 ± 3.7*	53.6 ± 3.1*	53.6 ± 4.1*	51.7 ± 3.5 [bc*]	52.0 ± 3.6 [bc]

[a] the mean value is significantly different from Measurement 0
[b] the mean value is significantly different from Measurement 1
[c] the mean value is significantly different from Measurement 2; $p < 0.05$
* the mean value of this variable calculated by Piechaczka's formula (i.e., the anthropometric method – ANT) is significantly different from the mean value measured by the BIA method; $p < 0.05$

Table 2. Subjects' body composition as measured by Piechaczka's method (i.e., the anthropometric method – ANT) and bioelectrical impedance analysis for two levels of physical activity (STANDARD and ATHLETIC)

	BIA_{ATH}	BIA_{STA}	ANT
FAT (%)	22.0 ± 5.3	29.7 ± 5.1 [a]	27.4 ± 2.7 [a]
FAT (kg)	16.1 ± 5.3	21.6 ± 5.6 [a]	19.8 ± 3.6 [a]
LBM (kg)	55.6 ± 2.6	50.1 ± 2.1 [a]	52.0 ± 3.6 [a]
Water (kg)	40.7 ± 1.9	36.7 ± 1.6	

[a] the mean value is significantly different from the values measured by BIA_{ATH}, $p < 0.05$

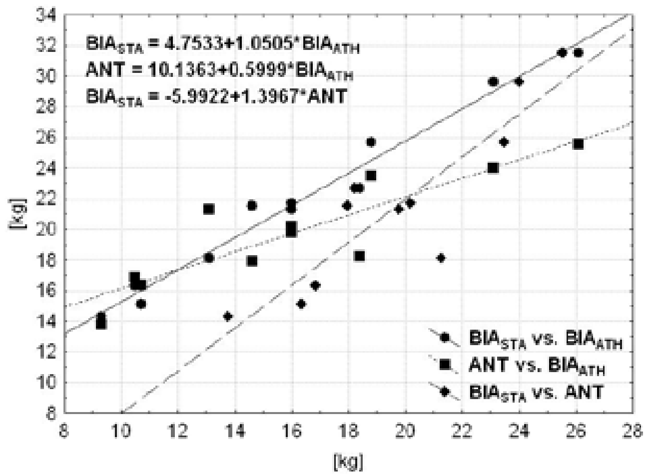

Figure 1. The linear relationship between fat tissue (kg) measured by bioelectrical impedance analysis for two levels of physical activity – STANDARD (BIA_{STA}) and ATHLETIC (BIA_{ATH}) – and fat tissue (kg) estimated by Piechaczka's equation [14] (anthropometric method – ANT)

for a standard level of physical activity and BIA_{ATH} for an athletic level of physical activity) as well as by the anthropometric method (ANT), are shown in Table 2 and Figure 1. Body water content was not significantly different between both physical activity levels of the BIA method, although the difference was found to be 9.8%. Analysis of lean body mass and body fat values found significant differences between the BIA method's ATHLETIC (BIA_{ATH}) physical activity level versus those values attained by the STANDARD (BIA_{STA}) physical activity level and the values estimated by the anthropometric method (ANT). By themselves, the results obtained by the BIA method's STANDARD physical activity level and those by the ANT were not significantly different. FAT (%) and FAT (kg) measured by BIA_{ATH} significantly correlated to both BIA_{STA} ($r = 0.98$, $r = 0.99$, respectively) and the values obtained by ANT ($r = 0.69$, $r = 0.88$, respectively). A significant relationship was also found for FAT (%) and FAT (kg) between BIA_{STA} and ANT ($r = 0.67$, $r = 0.90$, respectively). In addition, the variable LBM (kg) as found by BIA_{ATH} was also found to have significant correlation between the values obtained by BIA_{STA} ($r = 0.96$) and ANT ($r = 0.64$). However, LBM (kg), was found to have no significant relationship between BIA_{STA} and ANT ($r = 0.60$).

Discussion

Ascertaining an individual's body composition is of great practical importance in assessing the dynamic changes of various body components during both recreational and sports training. As was found in literature, a number of studies focused on evaluating the changes in both body mass and fat in athletes. Reilly [5] suggested that football players accumulate fat during the offseason and lose more body mass during preseason training than at the beginning of the competitive season. In this study, an increase in body mass and fat levels was observed during the preseason training period and later a decrease in these values at the beginning of the competitive season. Nonetheless, the fat values were not significantly higher when compared to the measurements taken before the start of preseason training.

Literature on the subject also indicates that the body fat percentage of female volleyball players to be in the range of 11.7–27.1% [3, 17]. In Malousaris et al.'s study [3], players from the A2 division were characterized by a body fat content of 24.1 ± 2.6%. Depending on the player's position, the smallest body fat content was among sweepers, at 21.4 ± 3.1%, while the largest body fat content found among receivers, at 25.7 ± 3.4%. Although the body fat values obtained in our study seem to be similar, body fat percentage in Malousaris et al. [3] was calculated by Siri's formula [18] while this study used Piechaczka's formula [14]. As such, when comparing the results from different authors, the various formulas for estimating body fat content should be taken into account. For example, Durnin's method, which was used by Malousaris et al. [3], gives higher values of body fat content than Piechaczka's method. As a whole, the reported BMI values for female volleyball players of different ages, different nationalities and different competitive levels oscillates between 20.5–22.5 kg/m^2 [3, 19]. The results obtained in our study found an average BMI value of 25.5 kg/m^2 and was similar to what was found by Gualdi-Russo and Zaccagni [19].

Many studies which have employed several measurement methods to assess body composition found different correlation coefficient values among the various methods, with one of the reasons being the varying fat content of the study subjects [8]. In our study, significant correlation was found between the measurements obtained by two different methods as well as for those measurements taken for two different physical activity levels. However, simple regression analysis found that smaller differences occur between the methods for periods of higher body fat values.

Another difficulty which arises when interpreting the results from different authors stems from what initial assumptions are considered about the study subjects' physical activity levels, which leads to significant differences among the measured parameters. Thus, despite a high reproducibility of results, the qualitative interpretation of certain findings at a given measurement range can be fraught with uncertainties related to rather subjective assumptions that determine physical fitness levels. Although this study has shown a significant correlation in the measurements of both methods, the average body fat percentage of the subjects obtained by the bio-impedance method for an ATHLETIC level of physical activity (22.0%) was significantly lower than the STANDARD level (29.7%) and for body fat calculated by the anthropometric method (27.4%). As was previously mentioned, researchers that deal with this issue have no clear consensus as to the results that both methods obtain.

Some authors [20, 21] state that bioelectrical impedance analysis overestimates body fat percentage, others [20, 22] claim that it underestimates this value, while even others [10] find that it provides accurate results. This lack of consensus may result from the application of different research methods of body composition: anthropometric measurements that use skinfold thickness were performed on different parts of the body with different conversion formulas while bioelectrical impedance analysis used various types of body composition analyzers. Besides this, rarely have studies been conducted on top athletes. In this study, the BIA method set at the ATHLETIC level of physical activity underestimated body fat content while overvaluing fat levels when set at the STANDARD level when compared to the results of the anthropometric method.

Conclusions

1. Throughout the 2010/2011 season, a significant increase in body fat during preseason training period was observed, which insignificantly decreased at the beginning of the competitive season.

2. A qualitative interpretation of the results provided by BIA is subject to error due to rather subjective assumptions that determine physical fitness levels as well as any associated changes in fitness levels in the event of a marked increase in workload intensity (e.g., during a training period)

3. Despite the high correlation of results obtained by both methods (at Measurement 4), the mean values of body composition were significantly different from the rest of the measurements only when using the ATHLETIC level of physical activity in the BIA method. Hence, when monitoring the impact of exercise or diet on body composition, it is not recommended to use both methods interchangeably.

Acknowledgments
The study was supported by the Ministry of Science and Higher Education (Grant No. AWF-Ds.-150).

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Paper received by the Editors: May 11, 2011
Paper accepted for publication: December 20, 2011

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