

BODY MASS INDEX AND BODY FAT CONTENT IN ELITE ATHLETES

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Abstract

The aim of this study was to evaluate body fat content (BF) of elite athletes obtained by two different field methods for body composition measurements and to compare it with body mass index (BMI) values. The research was conducted on 40 male athletes (20 runners and 20 handball players) and 30 non athletes. BF was calculated from the skinfold values (BF_{sft}) and estimated using a hand-held impedance analyzer (BF_{bia}%). Body mass index, waist to hip ratio (WHR) and waist to stature ratio (WSR) were calculated from adequate anthropometric values. Comparing the BF content between non athletes and two different sport groups, significant difference was found in all parameters between runners and non athletes ($p < 0.05$). Significant difference was found between BF values of runners and handball players ($p < 0.05$). Runners have had significantly lower BF, estimated by both methods. They also have had significantly lower WHR and WSR ($p < 0.05$). In the group of athletes and non athletes with BMI higher than 25 kg/m^2 , or lower than 20 kg/m^2 , comparing with others, no significant difference was found in BF_{sft} and WHR. BMI is not a good predictor of BF, because it does not provide specific information about body fatness, but rather body heaviness. Bioimpedance and anthropometry methods could be used to monitor non obese subjects in clinical routine and population based studies. For BF estimation in athletes, we recommend anthropometry, rather than bioimpedance because of inter individual and inter sports variations in arms length and regional masculinity.

Keywords: body fat, BMI, body composition, anthropometry, athletes

Introduction

Athletic performance is partially influenced by body composition characteristics of an athlete. Measurements of total or whole body fat content range from indirect estimates based on compartmental modeling approaches, to more direct measures of adipose tissue volume, such as in-vivo magnetic resonance imaging – MRI (Goodpaster, 2002).

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Bioelectrical impedance (BIA) and skinfold thickness (SFT) techniques, so-called field methods, are simple, readily available and noninvasive ones, along with the advantage of being radiation free. BIA and SFT method could be used to monitor non obese subjects in clinical routine and population based studies. The prediction equations are derived from lean subjects (Erselcan et al. 2000), and the prediction was generally good at a population level (Deurenberg et al. 2001).

Body mass index (BMI), like all anthropometric measurements, is only a surrogate measure of body fatness. In specific groups such as athletes and women, military personnel, police, firemen, etc., they are considerably leaner than indicated by their BMI. This relationship holds for most sport personnel, even down to the very low BMI associated with elite runners (Prentice, 2001).

The aim of this study was to evaluate body fat content of elite athletes obtained by two different field methods for body composition measurements and to compare it with BMI values.

Methods

The research was conducted on 40 male athletes, with average age 20.8 years, who have been active athletes for 7.8 years. They have been divided into subgroups, according to their sport specialties: 20 runners (active for 6.0 ± 3 years) and 20 handball players (active for 9.5 ± 4 years). They were all healthy, and voluntarily participated in the study. Control group was consisted of 30 non athletes, medical students, and they were not participated in any sport activity in the past 6 months.

The study was approved by the Ethics Committee of the Medical School of the University of Novi Sad and the investigation was performed according to the principles outlined in the Declaration of Helsinki.

Anthropometric measures, used in this research, were: Body weight (W), body height (H), 7 skinfolds (chest, midaxillary, triceps, subscapular, abdomen, anterior suprailiac and mid thigh skinfold thicknesses) and 5 circumferences (arm relaxed, arm flexed and tensed, waist, chest and hip). All anthropometric measurements were conducted under the recommendations and rules given by Heywarth and Stolarczyk (1996). At each skinfold site, measurements were conducted with Holtain-Koln caliper, to the nearest 0.1mm. Girths were measured with a flexible steel tape and all circumferences were recorded to the nearest millimeter.

After that, values of body mass index (BMI), waist to hip ratio (WHR) and waist to stature ratio (WSR) were calculated. Body mass index ($\text{BMI} = \text{kg}/\text{m}^2$) was derived as $\text{weight}/\text{stature}^2$, waist to hip ratio – WHR – was calculated as waist circumference divided by hip circumference, and waist to stature ratio – WSR – as waist circumference divided by height. For normal values of BMI, the references from World Health Organization were used (WHO, 1997) – BMI 18.5 to $24.9 \text{ kg}/\text{m}^2$ for lean individuals, border values from 25 to $29.9 \text{ kg}/\text{m}^2$, and obesity BMI higher than $30 \text{ kg}/\text{m}^2$.

For body composition analysis, total body fat was calculated from the skinfold and circumference values (BFsft), according to the recommendations given by Heywarth and Stolarczyk (1996). Other method for estimation of body fat was using a hand-held impedance analyzer - Omron BF300. During the measurement the instrument recorded impedance from hand to hand and consequently calculated body fat percentage from the impedance value and the pre-entered personal particulars (weight, height, age and sex). Two values were obtained: percentage of total body fat (BFbia%) and total body fat mass (BFbia).

All data were presented as mean values \pm standard deviation (SD). In statistical analysis, variance analysis – one way ANOVA was used, as well as Pearson’s correlation coefficient.

Results

Descriptive characteristics for athletes and non athletes are shown in Table 1.

Table 1

Characteristics of participants (non-athletes n = 30; runners n = 20; handball players n = 20)

	Non-athletes	Runners	Handball players
Height (cm)	182.2 \pm 5.6	182.5 \pm 6.1	188.8 \pm 4.2
Weight (kg)	79.3 \pm 8.5	74.0 \pm 7.9	91.6 \pm 8.3
Age (years)	19.2 \pm 0.97	18.2 \pm 1.5	23.5 \pm 3.7
BFsft (%)	11.2 \pm 4.5	8.4 \pm 3.0	12.1 \pm 4.4
BMI (kg/m ²)	23.8 \pm 2.2	22.2 \pm 1.8	25.7 \pm 2.3
BFbia (kg)	10.2 \pm 3.9	6.8 \pm 2.3	13.0 \pm 4.5
BFbia (%)	12.7 \pm 4.1	9.2 \pm 2.9	13.8 \pm 3.6
Waist C (cm)	81.4 \pm 4.6	75.4 \pm 4.2	84.6 \pm 5.2
Hip C (cm)	100.0 \pm 6.1	94.7 \pm 4.2	101.9 \pm 4.3
WHR	0.82 \pm 0.03	0.80 \pm 0.02	0.83 \pm 0.03
WSR	4.24 \pm 0.32	0.41 \pm 0.02	0.45 \pm 0.03

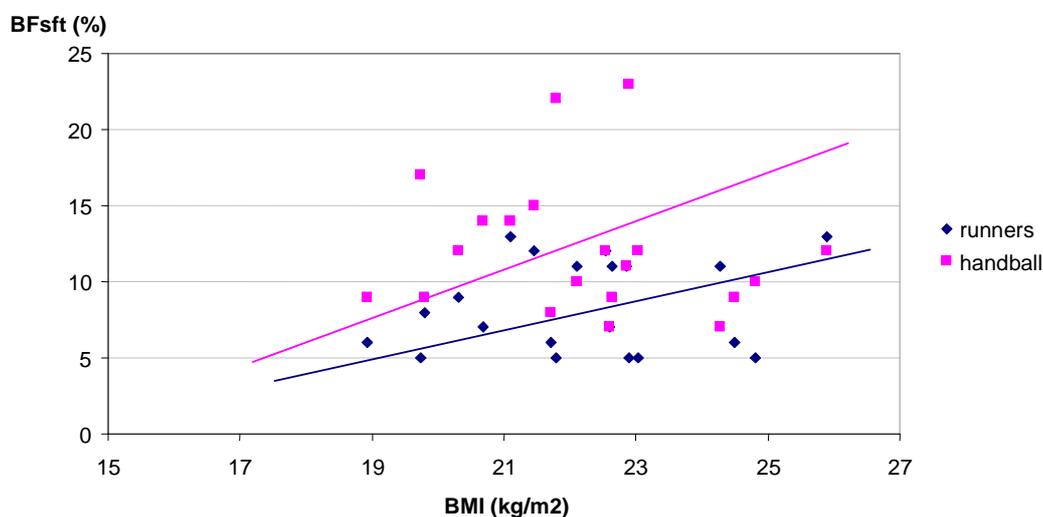
The average values for body fat content in athletes, calculated from skinfold thickness – SFT (BFsft) were 10.2 \pm 3.2% and 11.5 \pm 3.9% using bioimpedance (BFbia). Average BMI in athletes was 23.9 \pm 5.1 kg/m². No significant difference was found between BMI and body fat values of athletes and non athletes. Non athletes were lean, with average BMI 23.8 \pm 2.2 kg/m² and average body fat content 12.7 \pm 4.1% measured by BIA.

Comparing the body fat content (BMI, BFbia, WHR, WSR) between non athletes and two different sport groups, significant difference was found in all parameters between runners and non athletes ($p < 0.05$). On the other hand, between handball players and non athletes no significant difference was found in parameters of BFbia and WHR ($p > 0.05$).

Significant difference was found between body fat values of runners and handball players ($p < 0.05$). Runners have had significantly lower body fat, estimated by skinfold thickness and bioimpedance measurements. They also have had significantly lower WHR and WSR ($p < 0.05$).

All participants were divided into two subgroups, those with BMI lower than 24,9 kg/m² and those with BMI higher than 25 kg/m². Comparing body fat content between these two subgroups, there were no significant difference found in BFsft and WHR in runners and handball players. In the group of non athletes WHR was not significantly different ($p > 0.05$). Body fat content values measured by BIA were significantly different between these subgroups ($p < 0.05$). Comparing the body fat content (BFsft and BFbia) in the group of athletes with BMI lower than 19.9 kg/m² and those with BMI higher than 20.0 kg/m², there were no significant differences found ($p > 0.05$). There was no correlation between BMI and BF% in athletes, because BMI is a surrogate of body mass. Since athletes are heavier (especially handball players) due to their muscle mass, it directly leads to higher values of BMI. Mismatch between BMI and BF in athletes is shown in Figure 1.

Figure 1. Mismatch between body mass index (BMI) and body fat in athletes



Values of BF% calculated from SFT correlate with values measured from BIA ($r = 0.87$) in all athletes.

Discussion

Since athletic performance is partially influenced by the ratio of one's fat mass (FM) to fat-free mass (FFM), most athletes are concerned with their body composition.

The proportions of water, protein and mineral in the fat-free body, and thus the overall density of the fat-free body (FFBd) vary with age, gender, ethnicity, level of body fatness and physical activity level (Bottaro et al. 2002).

A variety of methods has been developed to determine body composition. Each of these methods has individual limitations in its assumption, calibration, accuracy and precision. In the present study, the most widely used two methods of body composition analysis, which are readily available in clinical routine, were evaluated in athletes and non athletes.

One alternative field technique that is simple, inexpensive and noninvasive is the measurement of subcutaneous fat thickness, or skinfolds, at selected sites. Since Matiega (1921) developed the first equations to estimate body fat based on skinfold thickness, several subsequent equations have been developed to estimate fat free mass or fat mass based on a two-compartment model from body density (Heyward & Stolarczyk 1996). The error in body fat estimates from skinfold thickness ranges from ± 3 to $\pm 11\%$, and is influenced by sex, race and age. The reliability of body fat estimates from either skin folds or circumferences is largely dependent upon the skill of the examiner (Goodpaster, 2002). Bioimpedance (BIA) is based on the principle that the electrical conductivity of the fat-free mass is greater than that of fat. The method assumes a cylindrical model of the body and a normal hydration of the fat-free mass.

In our study, average body fat percentages for runners were $8.4 \pm 3.0\%$, calculated from SFT and $9.2 \pm 2.9\%$ measured from BIA. Average body fat percentages for handball players were $12.1 \pm 4.4\%$, calculated from SFT and $13.8 \pm 3.6\%$ measured from BIA. According to Heyward and Stolarczyk (1996), average body fat percentages of runners are 8-16% and handball players are 10-12%. Average body fat percent in non athletes was $12.7 \pm 4.1\%$ measured by BIA.

It was shown in earlier studies (Baumgarthner et al. 1989; Fuller & Elia, 1989; Loy et al. 1998) that segmental impedance measurements (measuring only segments of the body as the legs or arms) also allow fairly accurate assessments of body composition. These segmental impedance instruments are easy to use and have the advantage that they are relatively inexpensive (Deurenberg et al. 2001).

Comparing the results of body fat percentage in our participants, it was shown that BMI is not a good predictor of BF%. It does not provide specific information about body fat, but rather body size. In the group of athletes and non athletes with BMI higher than 25 kg/m^2 , or lower than 20 kg/m^2 , comparing with others, no significant difference was found in BF% and WHR.

On the other hand, BF measured by BIA showed significant difference between these subgroups.

Estimation of body fat from BIA showed different distribution of body fat content than those calculated from SFT and WHR parameter in the group of athletes and lean non athletes. This observation might be explained by characteristics of BIA analyzer. In subjects with relatively larger arm muscles, the total amount of fat-free mass will be overestimated with BIA technique and hence BF% will be underestimated. Also, in subjects with relatively long arms, the measured impedance will be high and hence fat-free mass low and thus calculated BF% high (Snijder et al. 1999). There are reported differences in relative arm length among populations and it is known that within population groups the variability in arm length is high (Eveleth & Tanner, 1976).

WHR can be used as a good predictor of body fat content in lean subjects (Srdic et al. 2003). This parameter showed a good correlation with BF% in athletes ($r = 0.65$).

Comparing the results of body fat percent in athletes and non athletes, it was shown that there is a good correlation between values derived from SFT and BIA in the present study ($r = 0.82$ for runners, $r = 0.87$ for handball players, $r = 0.88$ for all athletes).

In conclusion, for estimation of body fat percent in athletes, we recommend skinfold thickness method, rather than bioimpedance, because of inter individual and inter sports variations in arms length and regional muscle mass. Body mass index is not a good predictor of body fat percent. It does not provide specific information about body fatness, but rather body heaviness.

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