Overweight in trained subjects – are we looking at wrong numbers? (Body mass index compared with body fat percentage in estimating overweight in athletes.)

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Abstract. Body mass index (BMI) is widely used as an index of obesity in adults. In trained population, individual with low body fat could be classified as overweight by BMI. To evaluate this problem, the purposes of this study were to determine the BMI and body fat percentage (BF%) of trained and untrained subjects and to evaluate the accuracy of BMI classification (≥25 kg·m^{-2}) as a prediction of overweight/obesity in trained subjects. The total number of 299 trained (basketball players) and 179 untrained male subjects participated in this study. Body height and body mass were measured; BMI was calculated for all subjects. BF% was determined *via* Tanita bioimpedance body composition analyzer. BMI ≥ 25 kg·m^{-2} and BF% > 20% were used to define overweight. There was no significant age differences. Body mass, height ($p < 0.01$) and BMI ($p < 0.05$) were significantly higher, although BF% was significantly lower ($p < 0.01$) in trained group when compared to untrained. Eighty-five trained subjects had a BMI of 25 or higher, indicating overweight. Of these, only three individuls had excess BF%. The results of the present study suggest that a BMI ≥ 25 kg·m^{-2} is not an accurate predictor of overweight in trained subjects.

Key words: Body mass index — Body fat percentage — Overweight/obesity — Trained subjects (athletes)

Introduction

The prevalence of adolescent and adult obesity is increasing at an alarming rate. Obesity is a serious health concern and is associated with many chronic diseases, including cardiovascular disease, diabetes, arthritis, gall bladder disease, certain cancers, and respiratory diseases (Pi-Sunyer 1993).

Body mass index (BMI) is widely used as an indicator expressing the level of obesity. According to the Expert Panel on the Identification, Evaluation and Treatment of Overweight and Obesity in Adults (see References: NHLBI 2000), BMI of 25–29.9 kg·m^{-2} is considered overweight and BMI ≥ 30 kg·m^{-2} is considered obese.

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In the recent study, Harp and Hecht (2005) used high BMI (≥25 kg·m^{-2}) as a synonym for obesity in professional football players. They reported overweight in 85% of athletes. This study was point of much of scientific debate.

Since BMI is obtained from numerical values of body height and mass, it obviously does not take into account body fat. However, BMI is thought to have a correlation with amount of body fat (Garrow and Webster 1985; Prentice and Jebb 2001) and is shown to be simple and stable indicator of obesity. It is not supported by some authors, who found low correlations between BMI and body fat percentage (BF%) in a large group of subjects aged 7–83 years (Deurenberg et al. 1991).

It is well known that the BMI classification system is valid for the general adult population, but it does have some limitations. One of these limitations involves the accuracy of using BMI for physically active, trained subjects. Using BMI for trained subjects can overestimate their level of body fat because muscle is denser than fat and it weighs more. It is especially true for trained subjects whose body fat can be normal or even low, but individual BMI is high.

Therefore, the use of BF% is more accurate than BMI in assessing obesity in physically active subjects (Deurenberg et al. 1991; Jonnalagadda et al. 2004; Ode et al. 2007). Despite potential limitations of BMI, it is still used to assess obesity not only in adults (Ogden et al. 2006) but in trained subjects and professional athletes, too (Ode et al. 2007). Therefore, it is critical to evaluate relationship between BMI and BF% in physically active population.

The purposes of this study were i) to determine the BMI and BF% of trained and untrained subjects and ii) to determine and evaluate the accuracy of the BMI classification of overweight (≥25 kg·m^{-2}) as a prediction of overweight/obesity in trained subjects according to measurement of BF%.

Materials and Methods

Subjects

Two hundred and ninety nine male basketball players aged 18 or over (mean ± SD; age, 21.57 ± 3.58 years, trained group) and 179 untrained men (21.05 ± 3.11 years, untrained group) participated in this study. All trained individuals were included in the Basketball league of Serbia. All basketball players had at least five years of training and during the current season trained 15–20 h per week. In order to standardize the effect of physical activity on body composition, we selected the sample of trained subjects participated in one sport and components of training were similar for all trained subjects. Control subjects were healthy, untrained adult men. They were randomly selected from students of Belgrade University who applied to participate in the study. The control subjects had not engaged in any formal exercise during the previous 2 years, had less than 8 h of physical activity per week and had never engaged in any athletic competition involving endurance activities. All subjects gave their written informed consent to the procedures approved by the Ethics Committee of the School of Medicine, University of Belgrade.

Anthropometric data

Body mass was assessed to the nearest 0.1 kg using a beam balance scale while individuals wear minimal clothing. Body height was assessed to the nearest 0.1 cm using a portable stadiometer fixed to the wall. The stadiometer and scale were calibrated periodically during the study.

BMI was calculated for all the participants as the ratio of mass (kilograms) divided by height (meters) squared.

For all individuals, BMI was classified using the National Institutes of Health standards for adults (<18.5, underweight; 18.5 to 24.9, normal; 25 to 29.9, overweight; >30, obesity).

BF% was measured using the Tanita bioimpedance segmental body composition analyzer (model BC 418). Subjects followed recommendations for body composition assessment by method of bioimpedance (Sigal 1996). They were asked to stand barefoot on the metal sole plates of the machine, and gender and height details were entered manually into the system *via* a keyboard. BF% was displayed and printed out.

Statistical analysis

All values are given as mean ± standard deviation (SD). Statistical analyses were carried out using the statistical package SPSS 10.0 for Windows (Chicago, IL, USA). The tests included *t* tests for testing differences between the two groups. Where appropriate, Chi square test was used for assess the significance of differences between variables. Statistical significance was set at $p < 0.05$.

Results

Anthropometric characteristics of the trained and untrained subjects are presented in Table 1. There was no significant differences for age between trained and untrained subjects. Body mass and height were significantly higher ($p < 0.01$) in the group of trained subjects when compared to untrained group. BMI was also significantly higher ($p < 0.05$) in trained group than in untrained (Table 1).

According to BMI classification system, subjects were distributed in the overweight categorie (BMI > 25 kg·m^{-2})

Table 1. Anthropometric characteristics of the trained and untrained subjects

	Group	Mean	SD	*p* (a vs. b)
Age (years)	a	21.57	4.58	>0.05
	b	21.05	3.11	
BM (kg)	a	94.45	12.44	<0.01
	b	77.97	9.84	
BH (cm)	a	199.11	8.54	<0.01
	b	183.37	8.97	
BMI (kg·m^{-2})	a	23.76	2.09	<0.05
	b	23.15	2.11	
BF% (%)	a	10.41	3.98	<0.01
	b	14.56	4.69	

BM, body mass; BH, body height; BMI, body mass index; BF%, body fat percentage; a, trained group (n = 299); b, untrained group (n = 179). The values are the means ± SD.

(Table 2). The maximal value of BMI in the group of trained subjects was 29.20 kg·m^{-2}, although in the untrained group was 30.04 kg·m^{-2} (BMI of 25–29. 9 kg·m^{-2} is considered overweight, or class-I obesity). In the group of trained subjects, 85 subjects (28%) have BMI in the overweight category, although in the untrained group, there were 37 subjects in this category (21%) (Table 2). This difference between trained and untrained subjects was statistically significant ($p < 0.01$).

BF% of the subjects is presented in Table 1. The average BF% of the subjects in the group of trained subjects was 10.41 ± 3.98%, and in the untrained group it was 14.56 ± 4.69%. The difference in BF% between trained and untrained subjects was statistically significant ($p < 0.01$). According to BF% recommendation for general population, the subjects were distributed in the overweight categorie if BF% is over 20 (Table 3).

According to World Health Organization (WHO) recommendation for general population optimal BF% is from 8 to 20% for male individulas, aged from 18 to 39 (Gallaghar et al. 2000). BF% from 20–25% is considered overweight, and above 25% – obese. In the group of trained, among 299 subjects, only three subjects (1%) had BF% higher than 20%. In the untrained group 17 subjects (9.5%) had BF% higher 20%. In this group 7 individulas were in overweight group, 10 in obese group. Nevertheless, 76 subjects in trained group had BF% less than 8%.

We found statistically significant correlation between values of BMI and BF% within group of trained and untrained subjects ($r = 0.535$; $p < 0.01$ and $r = 0.596$; $p < 0.01$, respectively). In the group of trained individuals with BMI over 25, there is nonlinear relationship between the two variables (BMI and BF%) in the assessment of obesity of trained subjects, accordingly correlation coefficient ($r = 0.161$, $p = 0.142$).

Table 2. Prevalence of body mass index (BMI) higher than 25, in the group of trained and untrained subjects

BMI > 25	Trained		Untrained	
	n	%	*n*	%
yes	85	28	37	21
no	214	72	142	79

Table 3. Ranges of body fat percentage (BF%) in the group of trained and untrained subjects

BF%	Trained		Untrained	
	n	%	*n*	%
<8%	76	25	3	2
8–20%	220	74	159	89
>20%	3	1	17	9

Chi-quadrate test showed statistically significant difference in prevalence of BF% > 20 in groups of trained ($n = 3$, 1.38%) and untrained ($n = 17$, 45.9%) subjects with BMI > 25 ($p < 0.01$).

Discussion

BMI has been used as a standard to define obesity. It is well known that BMI is an attractive anthropometric index because it meets the four requirements for an ideal method (Garrow and Webster 1985). The two instruments that are required (scale and tape measure) are inexpensive, require minimal training to use and are virtually maintenance-free, and repeated values can be obtained with good precision. Prentice and Jebb assessed the validity of BMI as a measure of obesity (Prentice and Jebb 2001). They have shown that the accuracy of BMI to detect overweight vary across trained subjects because of differences in body composition. BF% in trained subjects is attributable to greater muscle mass at a given body mass. It is well known that muscle is denser than fat, it weighs more. Therefore, the accuracy of BMI in assessing overweight in trained subjects is remaining question.

In the present study body mass, body height and BMI were significantly higher in trained group than in untrained. The mean BMI values in both groups were in the range of 18.5 to 24.9 kg·m^{-2} which is considered to be desirable for adults (Lee and Nieman 1993). Also, mean BF% in both groups were in the range 8–20% which is considered to be optimal for adults (Gallagher et al. 2000). All trained subjects had lower BF% compared with the untrained group.

In several studies the general BMI classification system has been used to assess obesity in athletes (Deurenberg et al. 1991; Jonnalagadda et al. 2004; Ode et al. 2007). Harp and Hecht (2005) used BMI ≥ 25 kg·m^{-2} to define overweight in professional football players. They showed that 97, 56, 26, and 3% of the NFL (National Football League) players had a BMI of 25 or higher, 30 or higher, 35 or higher, 40% or higher, respectively (Harp and Hecht 2005). This data are highly contradictory. More than sixty years before, in the same journal, Welham et al. (1942) reported that during World War II, many professional football players were deemed overweight by military service criteria and rejected for military service. However, using densitometry, Behnke showed that football players actually had smaller BF% (Behnke et al. 1995).

In our study, BMI in trained subjects was significantly higher than in untrained group. More than 28% of trained subjects had BMI in the overweight class (25–29.9 kg·m^{-2}). Regarding BMI, these data could suggest higher prevalence of obesity in trained subjects. Meanwhile, our study also indicates that only 1% of trained subjects had BF% over 20, compared with untrained where more than 9% had BF% over

20%. Similar to our results, the recent studies illustrated that higher BMI does not necessarily represent overfatness across athletic populations (Witt and Bush 2005; Nevill et al. 2006; Ode et al. 2007). However, we found strong correlation of BMI and BF% within both groups which may suggest that both parameters could be used in trained population but in ranges specifically derived concerning age, gender and physical activity level. Fact that in the group of untrained subjects with BMI over 25 kg·m^{-2} only 45.9% had elevated BF% showed that BMI could be also poor predictor of overweight in untrained persons. However, those results should be taken with caution, after taking in consideration that in our control group were only young individuals.

Influence of physical activity on BF% is not surprising. Study of large populations of men has shown that physical performance is negatively related to body fat and positively related to skeletal muscle mass (Mateigka 1921). Other investigators also examined the effect of exercise on anthropometric characteristics of trained subjects (Curtin et al. 1997; Harris et al 2003; Watts et al. 2003; Goh et al. 2004; Witt and Bush 2005).

Several methods have been used for measuring BF%, including dual-energy X-ray absorptiometry (Mateigka 1921; Curtin et al. 1997), skinfolds (Goh 2004), and hydrodensitometry (Hortobagyi et al. 1994; Kraemer et al. 2005). These methods of measuring BF% are more accurate than BMI, especially in trained subjects. In the present study, the BF% was measured using bioimpedance analyzer. Wang et al. (2000) reported that anthropometry and bioelectrical impendance are the most widely used methods for large studies, when no economic resource is available or when a quick measure is required. On the other hand, Segal (1996) illustrate that bioelectric impedance is another promising method for screening trained subjects, but it is difficult for trained subjects to follow the exercise, hydration and eating guidelines needed for reliable measurements.

Compared with the current recommendation BF%, in our study the BF% below 8% had 76 subjects (25%) in trained group and only 3 subjects (2%) in untrained group. The results suggest that recommendation for general population in assessing body fat could be underestimated. Despite the inherit recommendation 25% of basketball players are considered underweight. This illustrates the limitations in the current general recommendation for adult population. Consequently, a different, specific classification system should be used to assess BF% in trained subjects.

Previous studies recommended specific values for BF% in male trained subjects for different sports activities (Sinning 1974; Rusko et al. 1978; Siders et al. 1991; Hortobagyi et al. 1994). In Siders study, for basketball players, BF% at 12.4% was used as cut point (Siders et al. 1991). According to this finding, in our study 97 basketball players (32%) had BF% values higher than recommended.

Conclusion

In conclusion, the results of our study suggest that BMI ≥ 25 kg·m^{-2} is not an accurate predictor of overweight in trained subjects. Because of a larger muscle mass, BMI incorrectly classifies trained subjects as overweight. Our results suggest that in assessing overweight apart age and gender we have to consider the type and level of physical activity. On the other side, strong relationship of BMI and BF% within trained and untrained, showed that both methods could be used but with specifically derived cut-off points.

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