Summary

Body composition represents an unbreakable unity of the human body basic structure elements and involves a relative representation of the various constituent elements of the human total body weight. It is well known that body composition changes under the influence of continuous physical activity, and, therefore, it is one of the major components of fitness, and general health of the athletes. Therefore, this topic has become a major field of interest for many exercise and sport scientists as well as clinicians who specialize not only in different training methods but also in the prevention of and rehabilitation from major injuries. To date, having considered issues of accuracy, repeatability and utility, there is no universally applicable criterion or ‘gold standard’ methodology for body composition assessment in athletes. The main objective of this review was to give a short overview of methods for body composition analysis in athletes and to show and compare the latest data on their usefulness and reliability in order to find the best solution for practical everyday work.

Key words: Athlete, exercise; Body composition

Introduction

Body composition represents an unbreakable unity of the human body basic structure elements and involves a relative representation of the various constituent elements of the human total body weight [1]. Many studies suggest that body composition is, undoubtedly, significantly associated with physical activity in both sedentary population, and especially in elite athletes. It is known that continuous physical activity has a great influence on body composition, and therefore it is one of the five major components of fitness, and general health of the athletes [2]. Athletes’ body composition differs in certain morphological characteristics of persons who are not involved in sports and who are not physically active [3]. Athletes differ among themselves, too. Therefore, a phenomenon known as the 'sports morphological optimization' explains that the definitive athletes’ body composition depends on sports they do. Because of this, differences in the height and other body features strongly correlated with it are caused by the diversity of requirements that athletes have during the selection process. Differences in body fat and muscle percentage in athletes are caused by the adjustment of body composition to a variety of individual sports [2, 3].

Body composition assessment in elite athletes and everyone who is involved in physical activity is of great importance as a determinant of their performance. Therefore, several highly accurate methods for analyzing the structure of their bod-
ies have been developed. Laboratory methods include double-energy X-ray absorptiometry (DXA, previously DEXA), densitometry (underwater weighing-UWW), magnetic resonance imaging (MRI), neutron activation analysis and potassium-40 (K) analyses (TBK). Field methods include ultrasound, anthropometry, skinfold thickness (SF) and bioelectric impedance (BIA) [4–6].

However, regardless of the increasing number of technical solutions, the validity of the measured variables is still a key issue in defining and establishing the athlete’s body composition structure. Regardless of the fact that we are now able to measure a number of different body composition indicators we do not always register and get relevant information in relation to the effects expected to be achieved. Therefore, a serious problem regarding the choice of appropriate methods, and its accuracy and precision in the analysis of athlete’s body composition has arisen.

Bearing the above said in mind, the main objective of this review was to give a short overview of methods for body composition analysis in athletes and to show and compare the latest data on their usefulness and reliability in order to find the best solution for practical everyday work.

Material and Methods

The electronic database MEDLINE was searched from January 1990 to July 2013 and the keywords were: body composition assessment, anthropometry, DXA, BIA, hydrodensitometry, skinfold thickness measurement and athletes. The selected studies had to contain different profile professional athletes, aged 16 to 60 who had constantly been engaged in physical activity for at least 5 years, including the training duration of at least 15 to 20 hours a week. UWW (2C model) was selected as the criterion method for this review because of the fact that only a few studies used 3- or 4- component models. The studies encompassed in this review included one or more of the listed body-composition assessment methods: DXA, hydrodensitometry, inert gas dilution methods, plethysmography, infrared spectrophotometry (NIR), BIA and anthropometric methods. Having in mind that racial differences may potentially affect the results, the studies with black or Native American subjects were excluded. In addition, the studies including the athletes under the age of 16 and over the age of 60 were not taken into consideration.

Results

After preliminary literature search by selected keywords, one hundred and seventy six references were identified in MEDLINE. The preliminary literature scan produced 70 potentially relevant references, which were fully considered and analyzed. These, potentially relevant references were reviewed thoroughly, so that the total number of papers included in this systematic review was 27 (Scheme 1).

This systematic review included the studies conducted on football players (four studies), volleyball, basketball, and judo players, wrestlers, athletes, body builders, baseball players, triathletes, heptathletes and water polo players (one study), while six papers included different profile athletes.

Anthropometric methods vs. UWW, DXA, NIR, biochemical methods

Fifteen studies included in this systematic review dealt with the comparative analysis of different anthropometric methods for body composition assessment with BodPod method, DXA, hydro-
dienst, NIR or biochemical method of deuterium dilution. Many of these studies have compared BIA with other methods because it is rapid, noninvasive, and inexpensive; thus its application in the athlete’s body composition assessment is in the focus of scientific attention.

In the largest body composition comparative study on BIA and hydrodensitometry Lukaski et al. emphasized that conditions during the athlete’s body composition assessment using BIA method must be precisely controlled [4].

Andreoli et al. believe that body fat obtained using BIA and SF measurements is significantly overestimated [5].

The results of Dixon et al. have shown that BIA method underestimates percent body fat (%BF), and therefore it is not supported as a valid method [6].

Portal et al. have shown a positive correlation between %BF measured not only by SF method and BIA, but also by using Bod Pod method [7].

Oppliger et al. suggest the necessity to adapt methods of body composition assessment in order to improve the predictive value and accuracy of measurements in this population [8].

Yet another conducted study included the analysis of hydrodensitometry, SF method, BIA and NIR [9].

Clark et al. pointed to SF method as more reliable in assessing %BF than BIA method [10].

Houtkoop et al. believe that SF method gives more precise %BF estimation compared to NIR [11].

Williams et al. showed high Pearson product moment correlations among hydrodensitometry (HYD), BIA analysis and SF measurements [12].

Segal’s reviewing study also emphasized the importance of the strict measurement condition control [13].

Loenneke et al. have concluded that BIA significantly underestimates fat free mass index (FFMI) [2]. Recently Loenneke et al. determined the accuracy of BIA and SF method compared with DXA for estimating %BF [14]. The results of this study do not recommend the use of BIA or SF.

The studies conducted by Stewart et al., De Lorenzo et al. and Claessens et al. made a comparative analysis between DXA, BIA and SF measuring method [15–17]. These studies have yielded fairly uniform results although they were conducted on different athletes.

Moon et al. emphasized the necessity for the introduction of sport-specific adapted BMI [19].

**Comparison of different anthropometric methods.**

The comparative analysis of the application and reliability of various anthropometric body composition assessment methods in athletes was the topic of a separate group of studies with the highlight on the issue of BMI significance as an indicator of body composition of athletes.

Witt et al. showed that BMI method for evaluation of body composition on non-random sample of athletes often classified muscular athletes as obese [25].

Ode et al. had two main goals: to describe the relationship between BMI and %BF, and to define the accuracy of BMI as a measure of %BF not only in athletes but also in sedentary populations [20].

Mazic et al. studied the precision of BMI classification in overweight and obese athletes [21]. Their results showed that overweight in athletes could not be precisely estimated only by BMI >25 kg/m².

Garrido-Chamorro et al. determined the correlation between BMI and body fat, muscle and bone percentage [22]. These results showed that %BF was the only parameter that could affect BMI.

A step further was taken in the study of Neville et al. [23], which compared the %BF assessed by BMI and the SF data from three previously published epidemiological studies.

Huygens et al. suggested SF method as the most reliable one [24].

Only the results obtained by Ostojić differ from the previous facts [25].

Knechtle et al. have concluded that the body composition assessment by means of BIA leads to an overestimation of %BF compared with anthropometric methods [2].

Withers et al. performed a comparative analysis of %BF measured by means of body water (TBW), DXA method, hydrodensitometry and TBK [26].

As for the application and reliability of field methods to assess body composition of athletes, they are very few studies that use ultrasound for this purpose. This method is mainly used to determine the amount of visceral fat in obese humans [27]. Pineau et al. investigated the reliability of %BF measured by ultrasound, compared with DXA as a reference method [28].

**Discussion.**

Most researchers who study the active population (including athletes) now use techniques that provide only an approximation of body composition. It is well known that excess body fat and adiposity have become an aggravating factor of many physical activities, and because of this, these conditions are the reason for concern. On the other hand, the values of body composition can be used as a highly informative predictor for the planning and programming of training and nutrition in physically active population, as one of the most important factors for successful performance in many sports [1, 7].

There is an increasing number of studies that recommend many different technical solutions for body composition assessment in physically active population. However, the key issue in determining the structure of body composition is the validity of the measured results. A major problem occurs...
when it is necessary to choose the appropriate methods, regarding its accuracy, validity and precision in comparison with other methods. This systematic review expands and updates recommendations for the body composition assessment in athletes doing different sports.

Because of the importance of the body composition analysis in athletes, as a determinant of their performance, several highly accurate methods have been developed. The laboratory methods include DXA, hydrodensitometry, MRI, X-ray, neutron activation analysis and TBK. The field methods include ultrasound, anthropometry, SF measurement and BIA which are usually normalized and confirmed by standard laboratory methods [6–8].

Hydrodensitometry or UWW is one of the most precise indirect procedures for body composition assessment. This method is, on one side, very accurate, but on the other, very complex, time consuming and expensive. In addition, it requires special equipment and trained technicians [9–11].

On the other hand, there is a rapid, non-invasive BIA. Sixteen of the above mentioned studies have examined the reliability of BIA method in the estimation of body composition of athletes by performing a comparative analysis of %BF obtained by this and other relevant techniques, such as DXA, hydrodensitometry, deuterium dilution method and plethysmography. Although BIA is a quick, relatively inexpensive and noninvasive method for the body composition evaluation, the results are conflicting. The results obtained in 13 out of 16 studies (81%) indicate the relative unreliability of BIA method in the estimation of body composition in athletes. Five studies (31%) stated that BIA overestimated %BF, while one study (6%) indicated that these values were underestimated. In addition to the studies dealing with the unreliability of the methods, this systematic literature review included two studies giving recommendations for mandatory condition control to improve the accuracy of the results [12–15]. Only three studies (19%) highlighted the relative reliability of this body composition assessment method [16–18].

The results of the study conducted by Moon et al. have once again highlighted the need for the introduction of adapted “sport specific” BMI in order to get the most accurate body composition assessment in physically active population [19]. The most commonly used methods of body composition assessment in athletes, both in field and laboratory conditions, are primarily anthropometric methods. These methods measure the dimensions of the human body (body height, body weight, SF, volume and diameter of the limbs), and use them in the appropriate equations. The indirect assessment of the content of body fat, muscle and bone tissue of athletes by anthropometric methods is relatively easy. The height/weight ratio is used to construct the “reference value” table. Although in theory this is an excellent idea, in practice, however, there are some barriers - this ratio can be differently interpreted, and, in fact, a greater number of people must be measured in order to generalize the results. In addition, these scales / tables do not take into account individual differences in fat-free mass and relative fat mass (relative amounts of fat mass and lean body mass FM/LBM) in the body, and all this makes them quite unreliable in the body composition assessment in athletes. Anthropometry has some advantages compared to indirect methods such as hydrodensitometry, MRI and DXA. It is relatively inexpensive, non-invasive, fast and reliable and at the same time, does not require a specially trained person to perform it or the athlete’s cooperation [20, 21]. However, although it is well known that BMI is a good way to assess the level of nutrition in physically inactive population this method has a number of limitations particularly regarding its application in physically active individuals. Namely, the body composition analysis is based on weight and height, and does not take into account the percentage of body fat and BMI which are often above permitted levels, particularly in this population. If only anthropometric indicators of body composition are taken into account, these results may suggest obesity. However, it is usually the increased body mass that underlies everything since it is much denser than body fat and as such much heavier, whereas body fat percent may be even below the normal range [22]. So, while calculating of BMI is a widely accepted body composition assessing method in the general population, its application in athletes often fails to give the true picture of body structures and therefore many authors recommend the use of body fat as a more accurate parameter for obesity in physically active population [23, 24]. Many studies confirmed the above mentioned facts [25, 26]. A study conducted by Neville et al. even mentions the necessity of adapting and creating new recommendations and protocols specific to the physically active population in order to replace outdated models [23].

This systematic review of literature includes biochemical methods for body composition assessment as well. They are based on biological constants obtained by direct chemical analysis of the body. These methods include the estimation of potassium amount, the total body water and absorption of inert gas. The lean body component has a relatively constant amount of potassium, whose one part is in form of a natural isotope. Gamma rays from the K40 isotope can be detected by Whole Body Scintillation Counter (WBSC) method, which enables the estimation of the total amount of potassium in the body, as well as the lean body mass. The results of this method are very similar to those of hydrostatic weighing. Due to the cost and limited availability of WBSC, this method is practically neglected in the process of research and everyday work. Diffusion techniques rely on the characteris-
tics of substances to diffuse into tissues or compartments in the body so they can be detected. Markers, such as tritium and deuterium oxide (heavy water), antipyrine and ethanol, for example, can be used to estimate total body water. It can be difficult to estimate fat-free mass because the body contains nearly constant 73.2% of water, which is almost the total amount of water that is distributed through fat-free mass.

A study conducted by Withers et al. found a significant positive correlation between %BF measured by DXA, TBW and the total amount of potassium measuring. In addition, this study recommends hydrodensitometry for measurement of individual differences in TBW, %BF and bone mass [26].

The development of new technologies went further in 2013. The most recent studies dealing with the precise and reliable body composition analysis of athletes emphasize a new method of subcutaneous adipose tissue topography using Lipometer [28]. This method is presented as a quick, non-invasive, safe and accurate in body composition analysis, the latter being its most important characteristic. It is based on the application of optical devices whose head consists of a set of optical diodes that emit light passing through the skinfolds, and then enters the photodetector. The intensity of the detected light is then converted by computed tomography into the absolute thickness of subcutaneous fat (expressed in millimeters). The results of this pioneering studies suggest the reliability of this new method. However, although the initial results are promising, the accuracy and evaluation remain to be explored and compared with “reference methods” [27, 28].

**Conclusion**

It is important to determine athletes’ body composition not only to monitor the quality of the competition prospects, but also in order to assess the health risk. There are a lot of factors that can limit the validity and possibility to generalize findings of the body composition assessment in athletes. Taking into account, on the one hand, a number of studies which examined and compared the reliability and accuracy of different body composition assessing methods, and on the other hand, the specificity and diversity of the athlete’s body composition, not only with each other but also in relation to the sedentary population, it is very difficult to give the accurate estimation of the athlete body composition. Although the main goal of clinical doctors and practitioners is to apply the fastest and easiest methods such as bioelectric impedance analysis, most of the studies emphasize its uncertainties and recommend the mandatory control of measurement condition in order to improve the accuracy of results. On the other hand, anthropometric methods are widely used (especially the calculation of body mass index). Body mass index is often used to assess the obesity level. However, although it is a widely accepted method for assessing the level of nutrition in the general population, its use in athletes often fails to give the true picture of body structures and therefore many authors recommend the use of percent body fat as a more precise parameter in the physically active population. Finally, the rapid development of technology has brought a new method – subcutaneous adipose tissue topography using Lipometer. The pioneering studies seem promising, but further tests and comparisons with a “reference method” are necessary.

It should be noted that this systematic review includes only the articles from Medline database written and published in English, thus studies that could have given a significant contribution to improving the techniques of body composition analysis may have been excluded from the analysis. However, the results of the analyzed papers provide a wide and thorough review that not only can be helpful in finding a standardized criteria and methods for body composition assessment in athletes, but can also serve as a basis for further comprehensive research.

**References**

8. Oppliger RA, Nielsen DH, Shetler AC, Crowley ET, Albright JP. Body composition of collegiate football players: bi-


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