Original article

The usefulness of densitometry as a method of assessing the nutritional status of athletes. Comparison with body mass index

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A R T I C L E  INFO

Article history:
Received 18 May 2012
Accepted 23 September 2012

Keywords:
Densitometry
Body mass index
Fat mass index
Lean mass index
Athlete

A B S T R A C T

The body mass index (BMI) is used to assess nutritional status. The result in athletes may be overestimated due to increase in muscle mass.

Objective: To assess the usefulness of fat mass index (FMI) and lean mass index (LMI) determination as indicators of nutritional status and to compare the results with BMI.

Material and methods: We studied 28 amateur rugby players, male. After being subjected to whole body densitometry by dual X-ray absorptiometry, we determined fat and lean body mass together with other parameters. FMI (fat in kg/height in m²), LMI (lean in kg/height in m²) and appendicular muscle mass index (AMMI, arms and legs musculature in kg/height in m²) were calculated.

Results: Using BMI, 18 players were overweight and 4 obese type I. Considering FMI, 7 of them had normal values and high LMI and AMMI, one of them changed from overweight to obese and another one from obese to overweight. Of the 6 players with normal BMI, one of them showed fat excess and another one fat defect. The results changed the assessment of nutritional status in 39% of players.

Conclusions: Although BMI is an appropriate parameter in general population for the assessment of nutritional status, in athletes should be taken into account fat and muscle body percentage and their corresponding indices. The whole body densitometry appears to be a simple and reliable technique for this purpose.

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Utilidad de la densitometría como método de valoración del estado nutricional del deportista. Comparación con el índice de masa corporal

R E S U M E N

El índice de masa corporal (IMC) es utilizado para valorar el estado nutricional. En deportistas su resultado puede estar sobreestimado por aumento de la masa muscular.

Objetivo: Valorar la utilidad de la determinación mediante densitometría de los índices de masa grasa (IMG) y magra (IMM) como indicadores del estado nutricional, comparando los resultados con el IMC.

Material y métodos: Se estudiaron 28 deportistas amateur jugadores de rugby, de sexo masculino. Tras ser sometidos a una densitometría de cuerpo entero mediante absorciometría dual de rayos X, se determinaron entre otros parámetros la masa grasa y magra del cuerpo. Se calcularon los IMG (grasa en kg/talla en m²), IMM (magro en kg/talla en m²) e índice de masa muscular appendicular (IMMA, musculatura en brazos y piernas en kg/talla en m²).

Resultados: Utilizando el IMC, 18 jugadores presentaban sobrepeso y 4 obesidad tipo I. Al considerar el IMG, 7 de estos deportistas presentaban valores normales con IMM e IMMA elevados, uno pasaba de obesidad a sobrepeso y otro de sobrepeso a obesidad. De los 6 jugadores con IMC normal, uno de ellos mostraba exceso de grasa y otro defecto. Los resultados cambiaron la valoración del estado nutricional en el 39% de los jugadores estudiados.

Conclusiones: Aunque para la población general el IMC es un parámetro adecuado para la valoración del estado nutricional, en deportistas debe tenerse en cuenta el porcentaje de grasa y de musculatura determinando sus índices correspondientes. La densitometría de cuerpo entero resulta ser una técnica fiable y sencilla para este propósito.

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Introduction
The body mass index (BMI) or Quetelet index is defined as the quotient between the weight of an individual and his/her height squared. This index is used to assess nutritional status, being the method used in epidemiological studies and recommended by health organizations and medical societies because of its easy use and reproducibility. Nonetheless, its value is influenced by muscle mass, bone structure, genre and race. In addition, the relationship between the BMI and fat mass is not linear, particularly in children, youths and the elderly.

The determination of the nutritional status of the athlete in sports is important since its alteration allows evaluation of the adaptation to different types of training. A high proportion of fat mass is related to an increase in energy expenditure while a decrease reduces performance. A sudden change in the body composition may be a sign of health problems.

Dual-energy X-ray absorptiometry (DXA) determines body composition considering 3 components: lean tissue, fat and bone. The values obtained allow the calculation of the fat mass (FMI) and lean mass (LMI) indices as indicators of nutritional status.

Since the BMI in athletes may be overestimated due to the increase in muscle mass, the objective of our study was to assess the usefulness of DXA in the determination of nutritional status in athletes comparing the results found by the 2 methods.

Material and methods
The study group was made up of 28 Caucasian amateur male athletes all of whom belonged to the rugby team of the city. The mean age was 29 years (range: 19–43 years). Their physical activity corresponded to a training-play program of 5–6 h per week, competing in the regional league.

The study protocol included written informed consent, the measurement of height and weight using a scale with a stadiometer and whole body densitometry, and was approved by the Ethical Committee of the hospital. The study was performed in the month of October, that is, at the beginning of the regular sports season. Densitometry was carried out using a DXA Norland XR46 equipment performing a whole body scan with a resolution of 2.8 mm × 7.8 mm at a horizontal sweep speed of 200 mm/s. The athletes were requested to take off their clothing, rings, watches, and anything else which may cause artifact.

Among other parameters the study determined fat and lean mass of the whole body and its different parts including the arms and legs. Based on these parameters the FMI (fat in kg/height in m²) and LMI (lean mass in kg/height in m²) were calculated as were the appendicular muscle mass index (AMMI, musculature in arms and legs in kg/height in m²). The processing of the studies which included the definition of the areas of interest in the different parts of the body was carried out by the investigator. Likewise, the BMI was calculated (weight in kg/height in m²).

The evaluation criteria for BMI recommended by the World Health Organization (WHO) (normal between 18.5 and 24.99 kg/m²) were considered. According to the reference values of the National Health and Nutrition Examination Survey and those published by Schutz et al., normal FMI values were considered as below 6 kg/m². LMI measurements greater than 20 kg/m² and AMMI above 9 kg/m² were considered as elevated. The study group was divided into forwards (in general, those who fight for the ball and make up the static phases of the game) and the line of three-quarters (in general, rapid players who are important in the dynamic phases of the game) with the aim of evaluating possible differences.

For the analysis of differences between the mean values of the different variables the Mann-Whitney U test was used. Analysis of the correlations between the variables studied was performing using the calculation of the Spearman coefficient of correlation. Significance was considered above 95% (p < 0.05).

Results
The results of the different parameters determined are shown in 3 tables. Table 1 demonstrates the physical characteristics of the study subjects, the densitometry values and the results of the indices calculated.

Table 2 shows the median and ranges of the mentioned parameters considering the group of forwards and the three-quarters together with the statistical significance on comparison between the two groups. Significant differences were observed in weight, lean and fat mass and the 4 indices calculated (BMI, FMI, LMI and AMMI), reflecting the characteristics of the sport.

Table 3 depicts the results of the analysis of the correlations between the 4 indices calculated. The BMI was significantly correlated with the other 3 indices as well as the LMI and AMMI.

According to the classification of the WHO on nutritional status based on the BMI, of the 28 subjects studied, 18 were classified as overweight (BMI between 25 and 29.99 kg/m²) and 4 as type 1 obese (between 30.00 and 34.99 kg/m²). Only 6 athletes showed values within normality (between 18.5 and 24.99 kg/m²).

On applying the criteria based on the FMI the group considered as overweight, 7 presented normal values (>6.9 kg/m²) with an elevated LMI and AMMI (>percentile 90 and >9.9 kg/m², respectively), one became classified as type 1 obesity while the classification was not modified in the remaining 10 subjects, with 8 continuing to present an elevated AMMI.

Of the 4 type 1 obese based on the BMI, one thereafter presented an excess of fat on applying the FMI, with an equally elevated LMI and AMMI. Lastly, of the 6 players with a normal BMI (between 18.5 and 24.99 kg/m²), one presented an excess of fat and another, a moderate deficit.

Thus, the results obtained changed the evaluation of the nutritional status in 11 athletes, representing 39% of the players included in the study group (Fig. 1).

Fig. 2 demonstrates an example of the densitometry study in a subject badly classified as overweight based only on the BMI.

Discussion
Densitometry is considered a basic examination for the study of osteoporosis and other bone diseases. Its main indication is the determination of bone mineral density in the presence of risk factors of fracture such as advanced age, treatment with corticoids or physical inactivity. Likewise, the technique is used for monitoring patients submitted to treatments which may affect the bone marrow and evaluation of periprosthetic bone reabsorption.

DXA presents greater photonic flow compared to densitometers based on radioisotope sources, allowing a reduction in the time of acquisition and improvement in resolution and precision. Although the number of DXA equipment used in departments of Nuclear Medicine has diminished in recent years, this study represents a significant percentage of studies performed daily.

Overweight and obesity are characterized by an increase in body fat mass which has been associated with dyslipidemia, diabetes, arterial hypertension and some types of cancer. The distribution of body fat is used as a predictor of metabolic and cardiovascular diseases or early death.

The WHO has proposed the BMI as a parameter for the diagnosis of overweight and obesity. The values of normality have been
An athlete may have great
tissue or by muscle hypertrophy. Overweight is not synonymous
with an increase in fat.

The determination of body composition in athletes allows a
basal assessment as a reference for follow up during training. These
subjects present greater muscle development leading to an over-
estimation of the BMI. Thus, the FMI and LMI are more correct
parameters for assessment because they present greater precision
as indicators of nutritional status. BMD: bone mineral density; BMI: body mass index; FMI: fat mass index; LMI: lean mass index; AMMI: appendicular muscle mass index; TQ: three-quarters.

### Table 2
Comparison between forwards and the three-quarters players.

<table>
<thead>
<tr>
<th>Age, years</th>
<th>Weight, kg</th>
<th>BMI, kg/m²</th>
<th>BMD, g/cm²</th>
<th>Fat, kg</th>
<th>FMI, kg/m²</th>
<th>LMI, kg/m²</th>
<th>AMMI, kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>19–43</td>
<td>60–120</td>
<td>20–35</td>
<td>1.0–1.5</td>
<td>2.0–3.0</td>
<td>1.0–0.5</td>
<td>1.0–1.5</td>
<td>1.0–1.5</td>
</tr>
</tbody>
</table>

Values expressed as median and range together with statistical significance. BMD: bone mineral density; BMI: body mass index; FMI: fat mass index; LMI: lean mass index; AMMI: appendicular muscle mass index; NS: not significant.

defined by this organization and, in Spain, by the Spanish Society for the Study of Obesity (Sociedad Española para el Estudio de la Obesidad).

However, the BMI takes the total weight of the individual with-
out differentiating between the components of fat and lean mass
(muscles, viscera, bones, fluids and circulating proteins). Taking this
into account and the influence of genre, race and age, the precision
of the BMI to estimate body composition is debatable and may lead
to erroneous classification of a state of overweight or obesity.

An excess of weight may be produced by an increase in adipose

### Table 3
Correlations between indices.

<table>
<thead>
<tr>
<th>BMI</th>
<th>FMI</th>
<th>LMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.534</td>
<td>0.093</td>
<td>0.093</td>
</tr>
<tr>
<td>0.577</td>
<td>0.065</td>
<td>NS</td>
</tr>
<tr>
<td>0.795</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Values expressed as median and range with their statistical significance. BMI: body mass index; FMI: fat mass index; LMI: lean mass index; AMMI: appendicular muscle mass index; NS: not significant.
Fig. 1. Classification of nutritional status of the study group according to the BMI and FMI.

Athletes present a BMI above normal values due to the increase in muscle mass, with an adequate FMI. Considering these subjects as overweight would lead to a change in their alimentary regimen and/or an excessive increase in training time which could alter their athletic performance. The contrary case was also produced in our series: one of the athletes with a normal BMI presented a moderate deficit in fat (FMI of 2.11 kg/m²), which is equally associated with a reduction in performance.19

We found significant correlations between the BMI and the 3 other indices calculated (Table 3), coinciding with findings in the literature and being logical on considering that the body mass is the sum of lean and fat mass.20 The lack of correlation between the FMI and the LMI and AMMI demonstrates that modifications in one of the components do not represent changes in the other.

On evaluating the physical characteristics and the results of the parameters determined in the study group an important variability was observed as well as significant differences between the group of forwards and the three quarters. These findings are congruent on considering this type of sport. The anthropometry varies widely among rugby players, depending on the position on the playing field and the athletic level achieved. In general, the forwards present a greater body mass which is necessary for the static phases of the game, while the three quarters are more agile and rapid.21

Likewise, the percentage of athletes with an excess of fat is not surprising in our series. Rugby is an amateur sport in Spain and the motivations for involvement are varied, including an improvement in physical shape. Studies carried out including university teams in countries with a long tradition in this sport have also reported an excess of adipose tissue among their players. It is also known that the diet and nutrition, including alcohol intake, are areas traditionally little taken into account by amateur rugby players.21

Apart from the DXA there are other methods of assessing body composition. The most precise are the analysis of neutron activation and densitometry by immersion in water, with the DXA showing good concordance in results in comparison with these methods. Nevertheless, few centers in the world have these technologies, especially the first.22

Fig. 2. Example of an athlete badly classified as overweight using the BMI. With a height of 172 cm and a weight of 79 kg his BMI was 26.7 kg/m² (above normal values). On the other hand his FMI was 4.2 kg/m² with a fat mass of 12.544 kg (within normal values), the LMI was 20.8 kg/m² with a lean mass of 61.691 kg and AMMI of 10.6 kg/m² with a arm lean mass of 10.136 kg and a leg lean mass of 21.243 kg, both greater than normal values.
Anthropometry, which involves the measurement of adipose-cutanous folds, body perimeters, bone diameters and the application of formulas, is a method that is subject to intra- and inter-individual variations, with limited precision and reproducibility. Impedanciometry is based on the difference of resistance presented by the different parts of the body on the passage of alternate current. The method is affected by the state of hydration, the distribution of fat in the body and the content of hydrated glucogen in the muscle. Lastly, CT clearly differentiates between fat and muscle, also allowing assessment of segments of the organism and exact localization of the presence of fat in different anatomical areas. Its principal inconvenience is the radiation.\(^\text{23,24}\)

In relation to the limitations of our study, the relatively small sample size should be considered. Likewise, the fact that the processing of the studies was performed by a single investigator could carry the presence of bias or systematic error. Nonetheless, the grade of independence of DXA with respect to the observer in comparison with other procedures such as anthropometry should be taken into account.

In conclusion, although the BMI is an adequate parameter for the assessment of nutritional status in the general population, in athletes the percentage of fat and muscle should be taken into account with the determination of the corresponding indices. Whole body densitometry is a simple, reliable technique associated with minimal irradiation.

**Conflict of interests**

The authors declare no conflict of interests.

**Acknowledgments**

We would like to thank the players of the Club de Rugby Badajoz and, in particular, their President, Mr. Reyes Longares and their coach, Mr. Guillermo Vambrie.

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