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Original

Agreement of body composition methods in elite male football referees

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ABSTRACT

Objective: The current literature about the body composition of elite football referees is scarce and almost non-existent. Therefore, and in order to establish the level of agreement between bioelectrical impedance analysis (BIA) and dual energy X-ray absorptiometry (DXA) in elite football referees, the aim of this study was to compare fat mass (FM) and fat-free mass (FFM) values measured with these two different methods.
Method: A total of 30 male referees belonging to 1st, 2nd and 2ndB categories, and 36 assistant referees from 1st and 2nd categories in the Spanish national league participated in this study. Total and regional FM and FFM were assessed using a portable BIA analyser TANITA BC 418-MA (Tanita Corp., Tokyo, Japan) and DXA (Hologic Corp. Software version 12.4, Bedford, MA 01730). Agreement between methods was assessed by plotting the results in Bland-Altman graphs and the presence of heteroscedasticity was also examined. Differences between methods were analysed by two-paired samples *t*-test.
Results: For the whole group, BIA underestimated body fat percentage in 3.87 points (CI 95%=3.22-4.52; p=<0.01) and overestimated kg of total FFM in 3.56 points (CI 95%=3.08-4.05; p=<0.01), however, no heteroscedasticity was shown in any case (all p>0.05).
Conclusions: The present study suggests that according to DXA, BIA values calculated with a non-specific equation are underestimating total FM and, consequently, overestimating total FFM in male elite football referees.
Keywords: Adiposity; Body composition; Absorptiometry photon; Electric impedance; Soccer.

Concordancia entre diferentes métodos de composición corporal en árbitros de fútbol de élite

RESUMEN

Objetivo: La literatura científica existente sobre la composición corporal en árbitros de fútbol es todavía escasa. Por lo tanto y para establecer el nivel de concordancia entre el análisis de impedancia bioeléctrica y la absorciometría de rayos X de doble energía en árbitros de fútbol de elite, el objetivo de este estudio fue comparar los valores de masa grasa (MG) y la masa libre de grasa (MLG) medidos con ambos métodos.
Método: Un total de 30 árbitros pertenecientes a las categorías de 1ª, 2ª y 2ª división B, y 36 asistentes de 1ª y 2ª división de la liga española participaron en este estudio. La MG y la MLG tanto a nivel total como regional se evaluó utilizando la impedancia bioeléctrica TANITA BC 418-MA (Tanita Corp., Tokyo, Japan) y absorciometría de rayos X de doble energía (Hologic Corp. Software versión 12.4, Bedford, MA 01730). La concordancia entre métodos se evaluó con gráficos de Bland-Altman y también se examinó la presencia de heterocedasticidad. Las diferencias entre métodos se analizaron con la prueba T de Student para muestras relacionadas.
Resultados: Para el total de la muestra, la impedancia bioeléctrica infraestimó el porcentaje de MG en 3.87 puntos (IC 95%=3.22-4.52; p=<0.01) y sobreestimó los kg de MLG en 3.56 puntos (IC 95%=3.08-4.05; p=<0.01), sin embargo, en ningún caso se observó heterocedasticidad (todos p>0.05).
Conclusión: El presente estudio sugiere que, tomando como referencia la absorciometría de rayos X de doble energía, la impedancia bioeléctrica calculada a partir de una ecuación no especifica para árbitros, infraestima la MG y consecuentemente, sobreestima la MLG en árbitros de fútbol de elite.
Palabras clave: Adiposidad; Composición corporal; Absorciometría de fotones; Impedancia eléctrica; Fútbol.

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Concordância entre diferentes métodos de composição corporal em árbitros de futebol de elite

RESUMO

Objetivo: A literatura atual sobre a composição corporal de árbitros de futebol de elite é escassa e quase inexistente. Portanto, afim de estabelecer o nível de concordância entre a bioimpedância elétrica (BIA) e a absorciometria por raios-X de dupla energia (DXA) em árbitros de futebol de elite, o objetivo deste estudo foi comparar os valores de massa gorda (FM) e massa livre de gordura (FFM) valores mensurados com estes dois diferentes métodos.
Método: Um total de 30 árbitros pertencentes as categorias 1st, 2nd e 2ndB, e 36 árbitros assistentes da 1st e 2nd categorias da Liga Nacional Espanhola. A FM total e regional e a FFM foram avaliadas através de um analisador BIA portátil TANITA BC 418-MA (Tanita Corp., Tóquio, Japão) e DXA (Hologic Corp. Software versão 12.4, Bedford, MA 01730). A concordância entre os métodos foi avaliada através da plotagem dos resultados nos gráficos de Bland-Altman e a presença de heteroscedasticidade também foi examinada. As diferenças entre os métodos foram analisadas pelo teste t para duas amostras pareadas.
Resultados: Para o grupo como um todo, a BIA subestimou o percentual de gordura corporal em 3.87 pontos (IC 95% = 3.22-4.52; p = <0.01) e superestimou a kg total de FFM em 3.56 pontos (IC 95% = 3.08-4.05; p = <0,01), no entanto, nenhuma heteroscedasticidade foi mostrada em nenhum caso (todos p> 0.05).
Conclusões: O presente estudo sugere que, de acordo com a DXA, os valores da BIA calculados com uma equação não específica estão subestimando a FM total e, consequentemente, superestimando a FFM total em árbitros de futebol de elite do sexo masculino.
Palavras-chave: Adiposidade; Composição corporal; Absorciometria fóton; Impedância elétrica; Futebol.

Introduction

Body composition plays an important role in sports performance as well as in health-related physical fitness.[1] Generally, alterations on this physical fitness component can be due to psychological disorders or health problems, changes in the nutritional status, or as a marker of the athlete´s adaptation to the training process. It is well known that an excess of fat mass (FM) in athletes represents an inert load associated with an increased metabolic cost, a low power to weight-ratio, and a reduced acceleration.[2] In addition, a high proportion of FM is also strongly associated with low fitness levels but too little FM may result in the deterioration of both performance and health.[3]

Soccer refereeing, even not being considered a sport itself, requires high levels of fitness[4] and an adequate body composition in order to achieve the elite level.[5] Casajus et al[6] demonstrated a significant improvement in body composition over the last decade in this group of athletes. In a later study, the previous authors showed significant differences in the percentage of body fat (%BF) between referees and assistant referees of different categories.[7] Despite these studies focusing on body composition in soccer referees, their optimal body composition profile is yet to be defined. Most of the previously mentioned literature has been using either anthropometry or bioelectrical impedance analysis (BIA) as methods for assessment. Anthropometry requires a high level of expertise by the researcher to be an accurate and reliable method. In addition, when large samples are measured two or more researchers perform the measurements introducing inter-observer error into the %BF prediction. Nevertheless, with other equipment such as BIA, inter-observer error is removed, as BIA requires little knowledge for making a proper use of it, and is a simple, fast and inexpensive method for assessing body composition of large groups of people. Since its apparition, several validation studies have compared BIA with a reference method like dual energy X-ray absorptiometry (DXA) in male and female athletes with some very promising results.[8-10] The athletes participating in those studies were mainly adolescents and young adults; referees are on average 35-40 years old,[11] but present lower %BF values than their age-counterparts, as they are required to pass demanding physical fitness tests every four months and need high levels of cardiorespiratory fitness and muscular endurance to referee and complete an average of 11.7 km per match.[12] Thus, referees could be considered as a special population before generalising with the agreement studies between BIA and DXA.

Therefore, and in order to establish the level of agreement between BIA and DXA in elite soccer referees, the aim of this study was to compare FM and fat free mass (FFM) values measured with these two different methods. The main hypothesis was that BIA would be a valid device for assessing body composition in elite male football referees.

Methods

This comparative study was performed in accordance with the Ethical Guidelines of the Helsinki Declaration of 1975 (revised in Fortaleza, 2013) and was approved by the Research Ethics Committee [C.I. PI16/038]. Before the beginning of the study, written informed consent was obtained from all the participants after they were informed about the nature of the research.

Participants

A total of 30 male referees (age = 33.2 ± 5.0 years, body weight = 74.4 ± 5.7 kg, height = 180.6 ± 4.9 cm, body mass index = 22.7 ± 1.0) belonging to 1st, 2nd and 2ndB categories, and 36 assistant referees (age = 35.4 ± 4.6 years, body weight = 74.5 ± 7.5 kg, height = 177.3 ± 6.4 cm, body mass index = 23.6 ± 1.7) from 1st and 2nd categories in the Spanish national league participated in this study. All referees and assistants were Caucasian and apparently healthy and had taken part in the supervised medical and physical examination that the Referees Technical Committee on behalf of the Royal Spanish Football Federation (RFEF, in Spain) carries out every year. All measurements were performed in the evening (between 7-9 PM) along the season 2013-2014.

Experimental Design

Anthropometric parameters including height, using a stadiometer to the nearest 0.1 cm (SECA 225, SECA, Hamburg, Germany), and weight, using a scale to the nearest 0.1 kg (SECA 861, SECA, Hamburg, Germany) were measured without shoes and subjects wearing underwear following the procedures established by the International Society for the Advancement in Kinanthropometry (ISAK). Body mass index [BMI = weight (kg) / height^2 (m)] was also determined.

A portable 8-polar BIA analyser TANITA BC 418-MA (Tanita Corp., Tokyo, Japan) with a 200-kg maximum capacity and 0.1 kg precision was used to estimate FM and FFM. Prior to the test, all participants were instructed to follow the BIA pre-testing guidelines (no alcohol or vigorous exercise in the previous 12 hours and no food and drink in the previous 3 hours prior to measurement, no food and drink excess on the day before measurement and urination immediately before measurement). The same standard conditions (room temperature, place, and device) were maintained for all measurements. The computer-programmed prediction equation referred to as a mode (athletic) was selected prior to the assessment. The in vivo coefficients of variation in measuring weight (kg) and %BF with BIA were 0.1% and 1.1% respectively.[13]

Details of DXA measurements carried out in our laboratory have been described elsewhere.[14,15] DXA equipment (Hologic Corp. Software version 12.4, Bedford, MA 01730) was calibrated daily with a lumbar spine phantom and with a step densities phantom when required by de DXA device following the Hologic guidelines. FM and FFM for the whole-body (FM_WB and FFM_WB), upper limbs (FM_UP and FFM_UP), trunk (FM_TR and FFM_TR) and lower limbs (FM_LL and FFM_LL) were determined from BIA and from the whole-body DXA scan. The upper and lower limb data were calculated as a mean of both, right and left limbs.

All the assessments (Anthropometry, BIA, and DXA) were performed by a sports scientist (ISAK Level 2) who had been fully trained in the operation of the scanner, the positioning of subjects, and the analysis of results, according to the manufacturer's guidelines.

Statistical analysis

Data are presented as mean and standard deviation, unless otherwise stated. The results of the Kolmogorov-Smirnov tests showed normal distribution in all the variables. Differences between referees and assistant referees for physical characteristics and body composition results were tested using independent-samples *t*-test. The statistical method described by Bland-Altman[16] was used to assess the degree of agreement between DXA and BIA for assessing FM and FFM. Differences were plotted against the average of FM and FFM evaluated with DXA and BIA ([X + Y] / 2), as recommended by Krouwer.[17] Validity and lack of agreement between methods was assessed by calculating the inter-methods difference and the 95% limits of agreement (inter-methods difference ± 1.96). Heteroscedasticity was examined by linear regression to determine whether the absolute inter-methods was associated with the magnitude of the measurement. Differences between methods were analysed by two-paired samples *t*-test.

An alpha-level of 0.05 was used for all significance tests. Effect sizes were calculated according to the methods proposed by Cohen,[18] and taking into account the cut-offs defined, the effect size can be small ($d \leq 0.2$), medium ($d > 0.2$ and < 0.8), or large ($d \geq 0.8$). Statistical analyses were conducted with SPSS for Windows (SPSS Inc., Chicago, IL, USA) version 22.0.

Results

The physical characteristics of the participants showed that the referees were taller (d=0.6 and p=0.02) and had lower BMI (d=0.7 and p=0.01) in comparison with assistant referees. No significant differences between groups were observed for age and BMI (both p>0.05).

Body composition variables are shown in table 1. All body composition variables were significantly different between DXA and BIA methods when the whole sample was analysed (d=0.7 to 4.2; all p<0.05). Analysing the sample by role (referees and assistant referees), exactly the same differences were found in both groups (d=0.6 to 5.3; all p<0.05).

Comparing role-groups by method, assistant referees had higher percentage of FM_WB than referees (17.8 vs. 15.6 % with DXA and 13.9 vs. 11.7 % with BIA; d=0.9 and 0.8 respectively; both p<0.05). Likewise, assistant referees presented higher values of FM_TR and FM_LL than referees (5.7 vs. 4.8, 4.8 vs. 4.2 kg and 6.7 vs. 5.6 and 2.8 vs. 2.4 kg measured with DXA and BIA respectively; d=0.6 to 0.7; all p<0.05). FM_UL was only significantly different between assistant referees and referees measuring with DXA (1.5 vs. 1.3 kg, d=0.8 and p<0.05) but a tendency (p=0.06) was also found in the same variable measuring with BIA (0.8 vs. 0.7 kg). No differences between assistant referees and referees were found for any value of FFM assessed with DXA or BIA (all p>0.05).

%BF and kg of FFM, inter-methods difference and 95% confidence interval of BIA and DXA by group have been calculated. In all cases, BIA underestimated the amount of total FM and overestimated the amount of total FFM, compared with DXA (all p<0.05). For the whole group, BIA underestimated body fat percentage in 3.87 points (CI 95%=3.22-4.52; p=<0.01) and overestimated kg of total FFM in 3.56 points (CI 95%=3.08-4.05; p=<0.01), however, no heteroscedasticity was shown in any case (all p>0.05). The Bland-Altman plots are presented in figures 1 and 2.

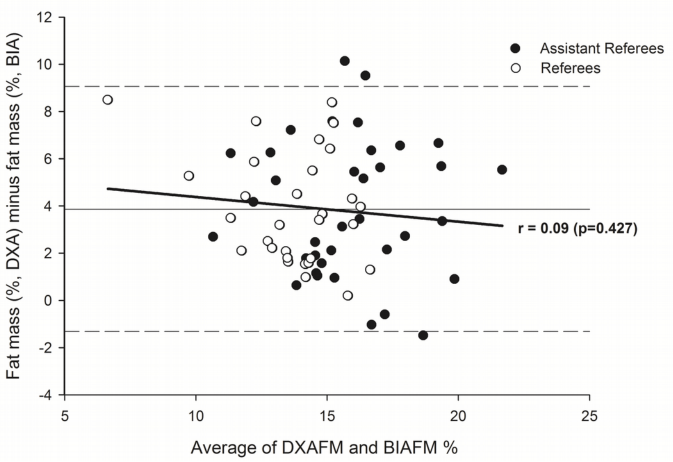

Figure 1. Comparison of %BF between BIA and DXA by Bland-Altman plots. Central line represents the inter-methods difference. Upper and lower broken lines represent the 95% limits of agreement (inter-methods difference ± 1.96 sd of the differences). The solid line in each plot represents the linear regression between %BF by DXA and differences between methods, its correlation (r) and significance (p).

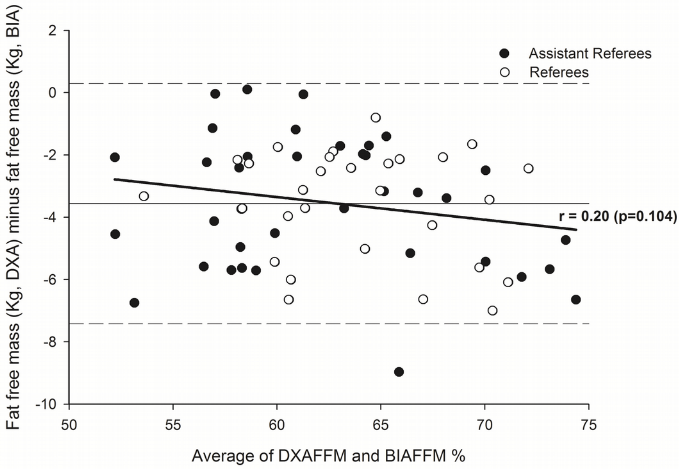

Figure 2. Comparison of Kg FFM between BIA and DXA by Bland-Altman plots. Central line represents the inter-methods difference. Upper and lower broken lines represent the 95% limits of agreement (inter-methods difference ± 1.96 sd of the differences). The solid line in each plot represents the linear regression between Kg FFM by DXA and differences between methods, its correlation (r) and significance (p).

Table 1. Body composition results (mean ± sd).

Variables	All (n = 66)			Referees (n = 30)			Assistant Referees (n = 36)			Independent Cohen´s *d*	
	DXA	BIA	Cohen´s *d*	DXA	BIA	Cohen´s *d*	DXA	BIA	Cohen´s *d*	DXA	BIA
FM_WB (%)	16.8 ± 2.7	12.9† ± 2.9	1.49	15.6 ± 2.0	11.7† ± 2.6	1.71	17.8* ± 2.8	13.9†* ± 2.8	1.35	0.91	0.81
FFM_WB (kg)	61.1 ± 5.3	64.7† ± 5.7	1.83	61.9 ± 4.6	65.5† ± 4.8	2.09	60.5 ± 5.8	64.0† ± 6.3	1.63	0.26	0.27
FM_UL (kg)	1.4 ± 0.3	0.8† ± 0.2	2.48	1.3 ± 0.2	0.7† ± 0.1	3.43	1.5* ± 0.3	0.8† ± 0.2	2.89	0.80	0.66
FFM_UL (kg)	6.4 ± 0.7	7.6† ± 0.9	2.23	6.5 ± 0.6	7.7† ± 0.8	2.33	6.3 ± 0.7	7.5† ± 1.0	2.08	0.30	0.22
FM_TR (kg)	5.3 ± 1.4	6.2† ± 1.6	0.72	4.8 ± 1.0	5.6† ± 1.5	0.69	5.7* ± 1.6	6.7†* ± 1.6	0.72	0.69	0.70
FFM_TR (kg)	28.8 ± 2.6	34.5† ± 2.9	4.16	29.1 ± 2.3	35.0† ± 2.5	5.33	28.5 ± 2.8	34.1† ± 3.1	3.68	0.23	0.32
FM_LL (kg)	4.5 ± 0.9	2.6† ± 0.7	2.13	4.2 ± 0.8	2.4† ± 0.5	2.03	4.8* ± 1.0	2.8†* ± 0.8	0.79	0.66	0.61
FFM_LL (kg)	21.7 ± 2.2	22.5† ± 1.9	0.86	22.2 ± 1.8	22.7† ± 1.6	0.57	21.3 ± 2.4	22.3† ± 2.2	1.11	0.42	0.20

DXA: dual energy X-ray, BIA: bioelectrical impedance, FM: fat mass, FFM: fat free mass, WB: whole body, UL: upper limbs, TR: trunk, LL: lower limbs.
* p<0.05, unpaired t-test, Referees compared to Assistants.
† p<0.01, paired t-test, DXA compared to BIA.

Discussion

The aim of the present study was to compare total FM and FFM values measuring them with two methods (BIA and DXA) in a population of male elite football referees. Our findings show that BIA may be underestimating total FM and overestimating total FFM compared to results from DXA in a sample of male elite football referees. Due to these differences exceed the established limits for a proper estimation, there is no agreement between both methods.

It is well known that FM increases through lifetime and that body composition is one of the main factors influencing exercise performance.[19] Referees and assistant referees are on average 10 to 15 years older than football players.[11] Experience is considered as a fundamental non-official prerequisite to officiate matches at the elite level. Therefore, referees usually reach their "golden age" career level around the age of 40.[20] For the previous reasons, referees are a unique population in terms of body composition and sport performance, being a group of athletes who need to achieve similar physical demands than their younger playing counterparts. In this line, Weston et al.[11] studied the effect of age upon the physical match performance in English premier league football referees demonstrating an age-related decline in elite-level football referees physical match performances. Despite that, the reduced physical match performances with increasing referee age did not impact upon the older referees' ability to keep up with play.

To our knowledge, this is the first study designed to compare body composition results from BIA and DXA in elite football referees, using two common methods for assessing body composition in elite athletes. One the one hand, BIA is a simple, quick, and non-invasive method for measuring body composition; it measures total body water and estimates FM and FFM. On the other hand, DXA is a means of measuring bone density and soft tissues by using two X-ray beams with different energy levels.

Our results showed that BIA underestimated total FM in 3.87 points and overestimated total FFM in 3.56 points. However, no heteroscedasticity was present for any plot. Similar studies have been carried out in elite athletes.[9,21-23] Firstly, Pichard et al.[21] found good agreement of FM and FFM between BIA and DXA in a group of female runners. Later, Fornetti et al.[22] showed similar results in a group of college-age female athletes from mixed sports, estimating BIA predictor error for %BF in ~1.8%. However, not all of the studies found good agreement between methods (BIA and DXA) in elite athletes. Esco et al.[9] showed that BIA provided significantly lower values for total FM (-3.3%) and significantly higher values for FFM (2.1 kg) in collegiate female athletes with limits of agreement of ± 5.6 points for BF% and ± 3.7 points for FFM. These values are quite similar to the ones reported in this study. Using a similar method to BIA, bioelectrical impedance spectroscopy (BIS), Svantesson et al.[23] found an underestimated FM of 4.6% in hockey players and 1.1% in football players, concluding that the evaluation of body composition with BIS in elite athletes should be cautiously interpreted, especially in individual participants. A possible explanation for the differences between studies is the diversity between the devices and software used. Even, Stewart and Hannan[24] pointed out that anthropometry (using four skinfolds) offers a better way of assessing body composition in male adult athletes from mixed sports than BIA, showing a BIA standard error for kg of FM in 2.8 kg. However, as mentioned earlier, the level of expertise required for performing anthropometry is considerably higher than the one for performing BIA.

Many studies have investigated the agreement between DXA and BIA[25,26] in different population groups, or have developed prediction equations for the assessment of %BF via BIA.[24] Despite several critics to the used of DXA as reference method for %BF and due to it has become one of the most frequently used methods for estimating human body composition even in athletes or active population, it was decided to use DXA as reference method in the present study. Moreover, the equation provided by the BIA manufacturer was used to estimate FM and FFM and not a specific one for the precise population that was being measured. To the best of our knowledge, just three studies earlier evaluated body composition in elite football referees.[5-7] Casajus et al.[5] reported an average %BF of 11.3% using skinfolds. Recently, Casajus et al.[6] found that an improvement in the body composition profile over the last decade had occurred in the elite referees in *La Liga (*1st category Spanish national league), by means of a reduction in BF %. The previous authors[7] reported an average of 10.8 BF% using BIA in referees and assistant referees from three different categories, showing lower %BF in referees than in assistant referees overall.

As previously explained, an optimal body composition may help referees to officiate matches and to promote into higher categories. FIFA fitness test requires little specialized equipment with protocols that and can be performed worldwide. BIA requires little time for completion without substantial investment and is easy to operate. The fact that its agreement with DXA in football referees is not great might be indicating that a specific prediction equation should be developed in order to increase this agreement and to provide a more accurate measure of FM and FFM in this group of athletes.

The main limitation of this study is the use of a BIA equation that is not developed specifically for elite soccer referees. On balance, the greatest strength to our study is the inclusion of all referees and assistant referees currently officiating one of the most important soccer leagues around the World, together with the correct standardization of measurement protocols.

In conclusion, the present study suggests that according to DXA, BIA values calculated with a non-specific equation are underestimating FM and overestimating FFM in male elite football referees. Other body composition measurements such as anthropometry or air displacement plethysmography could be taken into account for assessing FM and FFM in this specific population.

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