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Validity of body fat percentage through different methods of body composition assessment in elite soccer referees

Validação do percentual de gordura de árbitros de futebol de elite por diferentes métodos de composição corporal

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Abstract – The arbitration exercise in a soccer game requires high physical fitness and all federations apply physical tests to referees, including anthropometric tests, classifying them as fit or not for the role. The aim of this study was to assess the validity of the total body fat percentage (%BF) through different evaluation methods of body composition referenced in a four-compartment (4C) model. Cross-sectional study performed in 2018 with 21 elite male referees. %BF was estimated by 4 methods: anthropometry; bioelectrical impedance analysis (BIA); Dual X-ray absorptiometry (DXA) and air displacement plethysmography (ADP). Moreover, three and four-compartment (3 and 4C) models were calculated. Bland–Altman and intraclass correlations (ICC) analysis were performed to determine validity of all methods compared to a 4C reference. The results of one-way ANOVA revealed that there was no significant difference (F=1.541; p=0.182) between %BF analyzed by 4C model (15.98 ± 6.20), anthropometry (mean ± SD, 18.46 ± 7.03), ADP (16.19 ± 6.24), BIA (16.67 ± 5.30), DXA (20.33 ± 6.56) and 3C (16.92 ± 5.53). The Bland–Altman analysis showed that all methods analyzed overestimate %BF compared to the 4C model. The best agreement was obtained from the ADP evaluation (bias=-0.2), followed by BIA (bias=-0.6), 3C (bias=-0.9), anthropometry (bias=-2.4) and DXA (bias=-4.3). Validation assessed by ICC was excellent (ICC≥0.90) in most methods, except for anthropometry (ICC=0.80) and DXA (ICC=0.71). Overall, the results suggest that ADP, BIA and 3C were the best method to %BF evaluation. Nevertheless, anthropometry remains as a feasible method to monitor %BF of elite soccer referees.

Key words: Body composition; Soccer; Validity.

Resumo – *A arbitragem no futebol exige alto preparo físico. As federações aplicam testes antropométricos para classificar os árbitros como aptos ou não para a função. O presente trabalho teve como objetivo avaliar a validade do percentual de gordura corporal (%GC) aferido por meio de diferentes métodos de avaliação referenciado em um modelo de quatro compartimentos (4C). O %GC foi estimado por seis métodos: antropometria; bioimpedância elétrica (BIA); absortometria dupla de raios-X (DXA); pletismografia por deslocamento de ar (ADP); modelo de três e quatro compartimentos (3 e 4C). Bland-Altman e correlações intraclasse (ICC) foram realizadas para determinar a validade de todos os métodos em comparação com o modelo de referência 4C. Os resultados da ANOVA revelaram que não houve diferença significativa (F = 1,541; p = 0,182) entre o %GC analisado pelo modelo 4C (15,98 ± 6,20), antropometria (média ± DP, 18,46 ± 7,03), ADP (16,19 ± 6,24), BIA (16,67 ± 5,30), DXA (20,33 ± 6,56) e 3C (16,92 ± 5,53). Segundo Bland-Altman todos os métodos superestimam o %GC em comparação com o 4C. A melhor concordância foi obtida na ADP (viés= -0,2), seguida da BIA (bias = -0,6), 3C (viés = -0,9), antropometria (viés = -2,4) e DXA (viés = -4,3). O ICC foi excelente (ICC≥0,90) na maioria dos métodos, exceto para antropometria (ICC = 0,80) e DXA (ICC = 0,71). Os resultados sugerem que ADP, BIA e 3C foram os melhores métodos para avaliação do %GC. No entanto, a antropometria continua sendo um método válido para monitorar o %GC.*

Palavras-chave: *Composição corporal; Futebol; Validação.*

INTRODUCTION

Soccer is considered the most popular sport in the world and the referees are responsible for ensuring the application of the match rules. Therefore, referees must be able to keep up with the players to be in a good position to detect rule violations[1]. In this context, physical fitness is indispensable to carry out activities that require physical effort, such as refereeing a soccer match[2].

Physical fitness is related to body composition, and excessive body fat impairs the performance of activities - such as running - during the soccer match[2]. Referees members of the Brazilian Football Confederation (CBF) are evaluated by their performance of a physical test and body fat percentage (%BF)[3]. Therefore, three and seven skinfold Jackson and Pollock equations were validated for soccer professionals[4] and used to determine body density (BD), and %BF. Field methods (e.g., anthropometry and bioelectrical impedance analysis (BIA)) are the most frequently applied to monitor body composition in sports and clinical health with different levels of validity[5,6]. The knowledge of the validity of the different methods used to assess body composition in this population allows a better choice of the method to be used in the routine assessment of the %BF.

Two-compartment models (2C) split the body into fat mass (FM) and fat-free mass (FFM). Even though these methods are widely used to assess body composition, 2C models have an inherent error of assuming stable relative fat free mass compositions and a "constant" density[7]. The three-compartment (3C) model considers individual variability of total body water (TBW) or bone mineral content (BMC), and the four-compartment (4C) model takes both into account, making them more robust[7]. Air displacement plethysmography (ADP) is a convenient alternative to the underwater weighing system for measuring body volume (BV) and TBW through BIA, which has been used to assess TBW for multi-compartment equations in previous studies[8,9]. The 4C model is frequently referred to as the "gold standard" method, although there is no agreement[9]. Nevertheless, multicomponent models are still rarely used, as they require a lot of equipment to assess body composition, and are more time-consuming and expensive when compared to field methods[9].

Considering that (1) body composition is related to the soccer referees' performance, (2) they are constantly evaluated by %BF, and (3), to the best of the authors' knowledge, there are no studies comparing and validating body composition methods in this population: the primary purpose of this study was to assess the validity of %BF measured by anthropometry, air displacement plethysmography (ADP), BIA, dual energy x-ray absorptiometry (DXA) and 3C model referenced in the 4C model. The secondary purpose was to characterize %BF in elite soccer referees.

METHODS

Design and subjects

The sample size calculation was performed based on the formula proposed by Browner et al.[10], considering a test power of 0.9, α= 5% and an expected minimum correlation coefficient of 0.72[11]. The minimum correlation coefficient was defined according to Santos et al.[11], which aimed to assess the accuracy of

DXA in tracking body composition changes of physically active individuals. Thus, a sample of 17 participants was estimated, adding 20% for possible losses, so the final sample calculation consisted of 20 participants.

Twenty-seven soccer referees were recruited to participate in this study. The inclusion criteria were to be a soccer referee member of Federação Catarinense de Futebol (FCF) and integrate the elite national level category, which was evaluated for being associated with CBF. Six participants were excluded according to the exclusion criteria: female participants or those who had metal prostheses. The final sample consisted of 21 soccer referees (8 centers and 13 assistants), who are members of CBF, therefore, considered as elite referees. Data collection was performed by trained professionals and took place in July 2018, before the physical fitness test. Written informed consent was obtained from all participants. All procedures were approved by the Ethics Committee on Human Research of the Federal University of Santa Catarina (CAAE: 82584318.0.0000 and protocol 2.572.301) and were performed according to the guidelines laid down in the Declaration of Helsinki.

Study procedures

In order to characterize the population, all participants completed questionnaires regarding socioeconomic data and the International Physical Activity Questionnaire (IPAQ)[12], as well as body composition assessment (Figure 1). Moreover, skin color was evaluated by self-declared questionnaire.

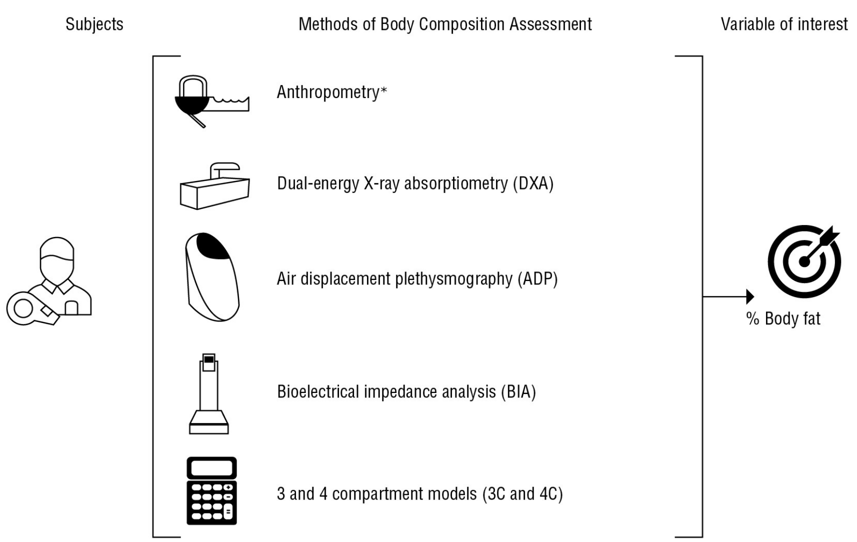

Figure 1. Study design. *Jackson and Pollock 7 sites equation (1978). Body fat percentage was calculated using Siri (1961).

Methods of body composition assessment

Preparation for analysis

All data collection was performed in the morning in random order at the Department of Nutrition in Brazil. Participants were instructed to fast overnight and refrain from exercising on the day before data collection. They were asked to wear fitted clothing (swimwear, top, lycra shorts), without metal zippers or studs, and remove earrings, rings, or any type of metal. Moreover, they were barefoot, and instructed to urinate 30 minutes before the body assessment. Participants were also asked to abstain from caffeine and alcohol 24 hours prior as well as discontinue diuretic medications[13].

Anthropometry

Body mass was obtained by an electronic scale (model RIW 200 Welmy®, Canoas, RS, Brazil), with a precision of 100 grams. Height was measured by a stadiometer (Alturaexata®, Belo Horizonte, BH, Brazil), with 1 millimeter of precision. The seven skinfold thickness measurements (chest, midaxillary, suprailiac, abdominal, triceps, subscapular, and thigh) were taken by two certified professionals with the International Society for Advancement of Kinanthropometry (ISAK) level 1 certification. The evaluators performed the same measures for every subject. The duplicate skinfold measurement was accomplished according to the ISAK protocol[14]. If the difference between both was higher than 12.5%, a third measurement was performed to estimate the median. The technical error of measurement (TEM) of intra-evaluator was 4.7 and 3.8%. The skinfold thickness was measured using a calibrated Lange skinfold caliper (Beta Tech Inc, Cambridge, Maryland), with 0 to 60 mm scale, a constant pressure of 10 g/mm^2 and a resolution of 1 mm. Body density was estimated with the Jackson and Pollock 7 site equation[15] and %BF was calculated by Siri[16] - %BF = [(4.95/BD) – 4.50] x 100, as performed in previous studies with referees[5,6].

Bioelectrical Impedance Analysis (BIA)

The BIA measurements were attained by applying an octopolar multifrequency device (InBody® 720, Biospace, Los Angeles, CA, USA). The calibration and evaluation were conducted according to the manufacturer's guidelines. All evaluations were carried out by the same researcher. The total %BF of each subject was directly given by the BIA device report.

Dual-energy X-ray absorptiometry (DXA)

All DXA scans were undertaken for the whole body scan and automatic mode by dual energy absorptiometry (Lunar Prodigy Advance, General Electric - GE®, Madison, WI, USA) using enCORE™ 2011 version 13.6 software for the analysis. The individuals were positioned on the scanning bed in the horizontal dorsal decubitus, with the palms of the hands lowered, close to the body, according to the manufacturer's protocol[17]. Then, two velcro straps were used to minimize the participant's movement during the scan and provide a consistent position for the analysis. The DXA was procedures and calibration were performed following the manufacturer's guidelines[17]. All scans were conducted by the same researcher and automatically analyzed by the DXA software. The total %BF of each subject was given directly by DXA device.

Air Displacement Plethysmography (ADP)

Body density was accessed by ADP using the BOD POD® (COSMED, Rome, Italy) calibration and procedures were performed according to the manufacturer´s recommendations[18]. The temperature was kept at 20°C during all procedures with an air conditioner, which also controls humidity. %BF was calculated using Siri's equation[16].

Three and four Compartment (3 and 4C)

BD was obtained by ADP and TBW by BIA. The 3C model was calculated using the Equation 1 described by Withers et al.[19].

$$BF\% = 211.5/BD - 78.0\,x\,(TBW\ /BM) - 134.8 \quad (1)$$

BD corresponds to body density (kg/m^3), TBW – Total Body Water (L), and BM - body mass (kg).

A 4C model was also implemented to estimate the %BF. Furthermore, BV was obtained by ADP and the bone mineral mass (Mo) by DXA. The 4C model described by Wang et al.[20] (Equation 2) was used to calculate %BF:

$$\begin{aligned} &Fat\ Mass\ (FM) = 2.748 \times BV - 0.699 \times TBW + 1.129 \times Mo - 2.051 \times BM; \\ &BF\% = (FM/BM)\,x\,100 \end{aligned} \quad (2)$$

BV corresponds to body volume (L), TBW – Total Body Water (L), Mo - bone mineral mass (kg), and BM - body mass (kg).

Statistical analysis

The statistical analysis was performed using STATA® software (StataCorp LP, USA) version 14.0. GraphPad Prism 5.0 (GraphPad Software, Inc.) was employed to create the graphics. According to the normality of data, continuous variables were expressed as mean ± standard deviation (SD) or median and interquartile range (IQR). Qualitative variables were described as absolute and relative frequency. Shapiro-Wilk was applied to verify the normality of data. To compare all six body composition assessment methods, the One-Way Analysis of Variance (ANOVA) was carried out. In addition, the Bland-Altman method was used to determine the bias and 95% limits of agreement (LOA) between all methods and 4C, as the reference method. The intraclass correlations coefficient (ICC) was used to evaluate the validity of measurements in comparison to 4C. Values less than 0.50, between 0.50 and 0.75, between 0.75 and 0.90, and greater than 0.90 are indicative of poor, moderate, good, and excellent correlation, respectively[21]. The significance level for all analyses was set at $p < 0.05$.

RESULTS

The sample consisted of 21 elite national level male soccer referees. Descriptive characteristics of the participants are shown in Table 1.

Table 1. Characterization data of elite national level male soccer referees (n=21). July 2018.

Variable	Mean (± DP)	Minimum - Maximum
Age (years)*	30.57 (± 3.41)	24 - 39
Body mass (kg)*	82.17 (± 7.84)	66.80 – 97.70
Height (m)*	180.01 (± 5.43)	170.80 – 188.60
BMI (kg/m²)*	25.31 (± 1.60)	22.63 – 28.39
Education	**N**	**%**
Incomplete higher education	4	19.05
Complete higher education	7	33.33
Complete postgraduate	2	9.52
Incomplete postgraduate	8	38.09
Skin color	**N**	**%**
White	15	71.42
Multiracial	3	14.28
Did not want to answer	3	14.28
IPAQ	**N**	**%**
Low	0	0.00
Moderate	4	19.04
High	17	80.95
IPAQ (MET-minutes/week)*	4488.52	IQR: 2320.0-4212.0
CBF Refereeing experience (years)*	3.74	IQR: 1.5-4.0

Note. BMI, body mass index; IPAQ, international physical activity questionnaire. #MW, minimum wage = R$ 954.00 Brazilian reais. *Continuous variables were presented as mean ± standard deviation and minimum and maximum values or as median and interquartile range depending on the normality of the data.

One-way ANOVA revealed that there was no significant difference (F=1.541; p=0.182) between %BF analyzed by 4C model (15.98 ± 6.20), anthropometry (mean ± SD, 18.46 ± 7.03), ADP (16.19 ± 6.24), BIA (16.67 ± 5.30), DXA (20.33 ± 6.56) and 3C (16.92 ± 5.53) (Figure 2).

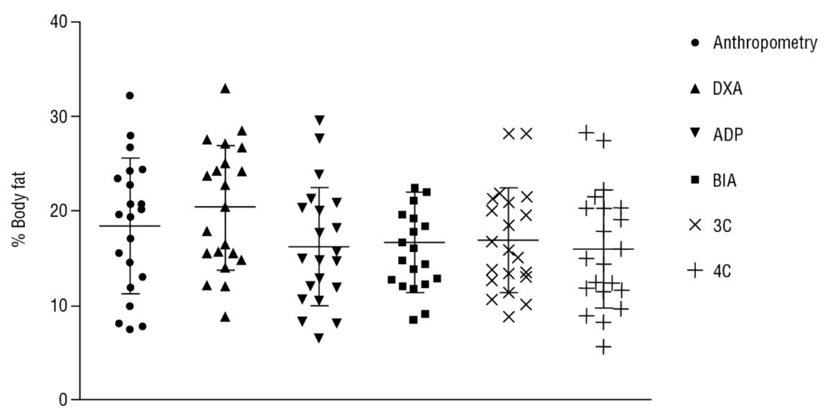

Figure 2. Mean % body fat according to the different methods of assessing body composition in elite national level male soccer referees. Data are shown as mean and standard deviation (n=21), analyzed by One-way ANOVA. The significance level for all analyses was set at p < 0.05.

ICC indicated that BIA, ADP and the 3C model exhibited excellent correlation, anthropometry indicated good correlation, and DXA showed moderate correlation compared to the 4C model (Table 2).

Table 2. Intraclass correlations coefficient of body fat percentage obtained by different methods in elite national level male soccer referees (n=21). July 2018.

Method of body composition assessment	ICC
ANTHROPOMETRY	0.80
DXA	0.71
ADP	0.94
BIA	0.93
3C	0.95

Note. ICC = intraclass correlation coefficient values. Intraclass correlations (ICC) analysis was performed and compared to the 4C model. ICC was considered an excellent correlation when ICC ≥ 0.90, a good correlation at 0.75 ≥ ICC< 0.90, a moderate correlation at 0.50 ≥ ICC < 0.75 and a poor correlation when ICC < 0.50.

The graphic representation of the Bland–Altman analysis using the 4C model as a reference is presented in Figure 3. All analyzed methods overestimate %BF compared to the 4C model. DXA was the higher bias, followed by anthropometry, 3C, BIA and ADP, respectively.

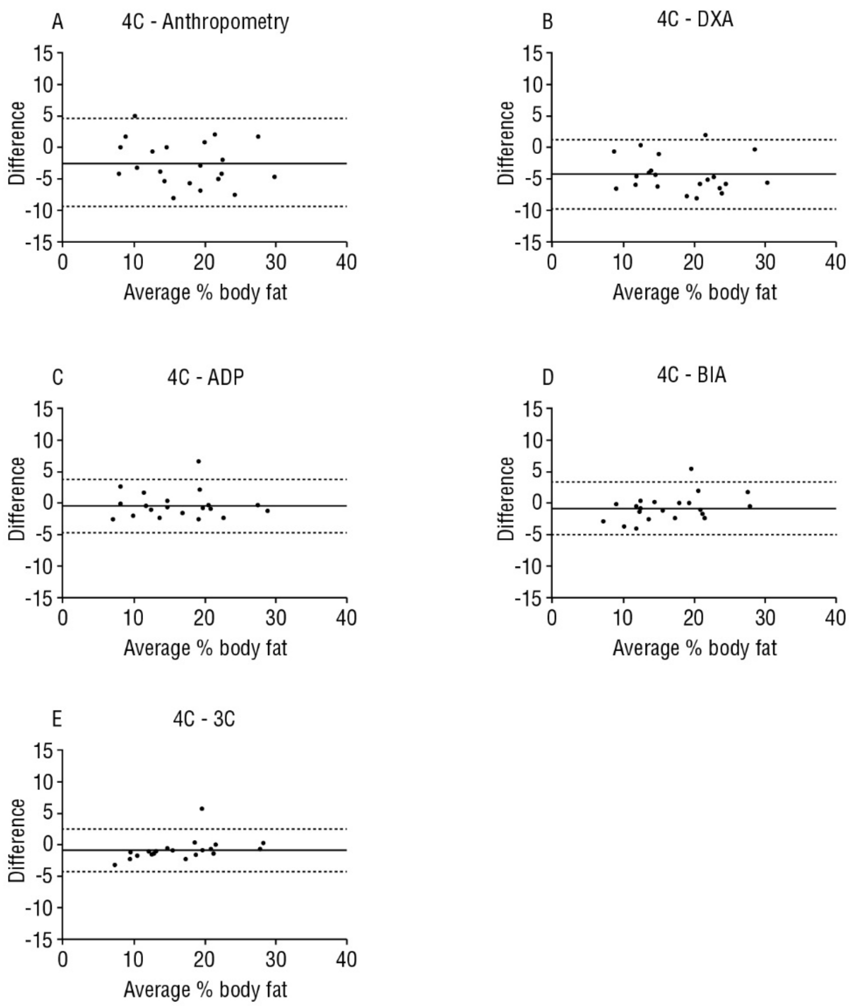

Figure 3. Bland-Altman graphs referring to the difference in mean % body fat compared to the 4C (4 compartment) model in elite national level male soccer referees (n=21). Difference in mean % body fat analyzed by 4C model and anthropometry (A), 4C and

dual-energy X-ray absorptiometry (DXA) (B), 4C and air displacement plethysmography (ADP) (C), 4C and Bioelectrical impedance analysis (BIA) (D), and 4C and 3C (3 compartment) models (E). The solid horizontal line represents the overall average of the differences, and the dashed lines show the range of 95% limits of agreement.

DISCUSSION

The variety of body composition analyses achieved in this research is still scarce in the literature, especially for soccer referees. The results observed in this study have great applicability in the soccer referee context, since they are constantly evaluated by their body composition. The primary finding reveals that most methods demonstrated an excellent correlation between %BF and the 4C model, except anthropometry and DXA, which presented a good and moderate correlation, respectively. Moreover, all methods performed overestimated the median %BF compared to the 4C model, highlighting DXA and anthropometry, which were overestimated by 4.3% and 2.5%, respectively. The secondary findings indicate that the %BF obtained by anthropometry (18.46%) are within the range related to previous studies with Brazilian referees[5,6], but higher than referees from other nationalities[22,23].

The 4C equation used in this study was validated in physically active men and women[24] and tested with BV and TBW by ADP and BIA, respectively[8,9]. Schubert et al.[25] compared the 4C model using ADP and underwater weighing derived BV and found no significant difference between them. All methods analyzed in the present study overestimate %BF compared to 4C, with DXA exhibiting the highest bias and ADP the lowest. ICC was excellent for ADP, but lower ICC was observed for DXA, indicating that the ADP, in addition to achieving greater agreement with the reference method, is more reliable than DXA. These results corroborate the findings of Schubert et al.[25] in 32 young healthy individuals (23.7 ± 4.7 years) of both sexes, where all the analyzed methods overestimate %BF compared to the 4C model. On the other hand, Nickerson et al.[26] evaluated 187 women and men with ages between 18 and 40 years and found that the %BF by anthropometry was lower than 4C. However, the BD equation used was not reported and the TBW value was obtained by underwater weighing, which may partially explain the difference.

Some factors are mentioned to explain the fact that DXA overestimated the %BF in lean individuals: changes in muscle metabolites and water content occur in this group due to physical exercise, such as increased muscle glycogen storage[27]. In addition, DXA was the only method that exhibited a moderate correlation when compared to the 4C model. At least in this population, DXA is not the best method for assessing body composition, with less correlation than other methods. One study investigated soccer referee body composition through DXA and reported lower values of %BF (18.9 ± 3.7 vs 20.33 ± 6.56) compared to the present study. However, this sample is composed of both sexes, and the authors did not mention the brand of the device used[1]. The %BF obtained by BIA (16.67%) and anthropometry (18.46%) is within the range reported in previous studies with Brazilian referees[5,6], but higher than Italia and Spanish referees[22,23]. BIA showed an excellent correlation and anthropometry a moderate correlation with 4C (ICC: -0.93 and 0.80), and the bias was lower for BIA (-0.7 vs -2.5). Apparently, the addition of the TBW variable in the

BIA assessment helps to control the intra and inter-individual variation of body hydration and contributes to lower bias than anthropometry.

Additional attention should be paid to BD, especially during extreme periods of life (pubertal growth and aging). The density of FFM is largely influenced by bone mineral because bone density is markedly higher than that of other components of the FFM[28]. During these special periods of life there is an unstable relationship between BMC and muscle mass in comparison to adulthood. Other factors of attention should be TBW, minerals and protein rapidly changing at the extremes of life, providing new ways of approaching the traditional body composition[28]. In adulthood, this condition is more consolidated, therefore, the estimates made from TBW and BD, namely in a multicomponent approach, are more stable and reliable[28].

On the other hand, the hydration status in BIA can also interfere with the measurement. A recent study evaluated FFM hydration in athletes and non-athletes and the authors found a highly significant correlation between the difference in the estimation error of the %BF by 2C vs the multiple-compartment model[29]. Gutiérrez-Marín et al.[30] demonstrated that differences in age, sex, and BMI can explain 30% of the variability in FFM hydration. Interestingly, BIA presents greater agreement with the reference method than 3C with biases of -0.7 and -0.9, respectively, which suggests that multiple-compartment models may be more sensitive to variations due to the constants assumed by each method that compose the equations. Despite this, 3C had a better correlation with 4C compared to BIA (ICC= 0.95 vs 0.93).

Body fat percentage of referees described in the literature evaluated by anthropometry using Jackson and Pollock 7-sites equation, the most used for assessment of the referees, range from 14.4 to 18.6%[5,6]. Casajús et al.[22] observed enhanced body composition through %BF reduction of elite Spanish referees over the last decade. The same improvement was not found in Brazilian referees, which showed, in the current study, an average of 18.5% BF evaluated by anthropometry. Nonetheless, a study conducted 20 years ago, with a similar population and methodology, found an average of 17.3% for centers and 14.4% for assistants[6]. Therefore, nutrition counseling and exercise programs would be recommended to improve their body composition and consequently, their performance in matches.

Limitations of the current study include the use of BIA to estimate TBW instead of the deuterium oxide (D_2O) and ADP to assess BV instead of underwater weighing (UWW) in the multi-compartment equations. However, it is important to highlight that both methods are validated and previously implemented in related articles[8,9], despite not being considered "gold standard". The bone mineral density (BMD) values found in the referees of the present study (data not shown) are generally high (90% of the sample). However, the variation from greater BD to bone mineral content is smaller in adults and, in this study, it was more homogeneous. According to BIA, hydration within the normal range was found in only 38% of the sample and may have influenced the results of the equation that considers these variables to calculate %BF. Additionally, the 4C equation proposed by Wang et al.[20] was developed using a healthy and non-athletic population but has been validated for the athletic population[24] and utilized in articles whose target participants were athletes or physically active individuals[25].

CONCLUSION

In conclusion, the results indicated that all analyzed methods overestimate %BF compared to the 4C model, even though within acceptable error thresholds. The best agreement was obtained by the ADP evaluation, followed by BIA, 3C, anthropometry and DXA. ICC showed excellent validity for BIA, ADP, and the 3C model compared with the 4C model as the reference method. Anthropometry and DXA presented a good and moderate correlation, respectively. Overall, the results suggest that anthropometry, the most used method for evaluating elite soccer referees, is a valid method for monitoring %BF compared to a robust model, such as 4C, as well as all the other methods tested.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee - Federal University of Santa Catarina and the protocol (no. 2.572.301) was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Authors LS and FSGD contributed equally to the work

Conceived and designed the experiments: FH and JC. Performed the experiments: LS, FSGD, LVS and CLKC. Analyzed the data: PFH, LS, FSGD, LVS and FH. Contributed reagents/materials/analysis tools: PFDP and YMFM. Wrote the paper: LS, FSGD, LVS, CLKC and FH.

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