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Original Article

Association between body fat percentage estimated by DXA and Jackson and Pollock equations in futsal players

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Abstract:
Futsal is a sport practiced by tens of millions of people around the world. Among its characteristics, the great variety of motor actions stands out, as well as the high intensity of effort, and the high demand that such a combination imposes on the body. Such dynamics demand rigorous monitoring of the athlete in several aspects, among which, is body composition. And since there are several equations to identify body composition by the percentage value of body fat that can be used in this population, there is no consensus on which is the most appropriate, and consequently, recommended for use. In view of the above, the manuscript aimed to analyze a possible association between body fat percentage (BF%) estimated with DXA and with three different body density (BD) equations for consequent estimation of %BF in male futsal athletes. To do so, the values obtained were submitted to analysis of variance, correlation, regression, and relative and absolute reliability. Although the BF% estimated with the three equations, seven skinfolds (7SF), three skinfolds 1 (3SF1) and three skinfolds 2 (3SF2), showed high or very high correlations with the value estimated with DXA, 7SF and 3SF2 led to overestimation of BF%, while the estimate with 3SF1 did not differ significantly from the value estimated with DXA. Furthermore, 3SF1 showed an absolute reliability that represents a difference of approximately half a percentage point compared to the estimate with DXA, an excellent relative reliability, and a coefficient of determination comparable to equations applied to the very profile of athletes for which they were developed. Thus, in the absence of a specific equation to estimate BD, and consequently %BF, in professional futsal athletes, the adoption of 3SF1 is recommended. It is also pertinent that future similar studies seek to reach a larger sample size, which enables the development of a specific equation for this public and seek to do the same with female professional futsal athletes.
Key Words*:* **Anthropometry, skin folds, body composition, futsal**

Introduction

Futsal is a sport organized and regulated by the International Federation of Football - FIFA (FIFA, 2020). According to the governing body, there are approximately 30 million practitioners at amateur and professional levels of this sport worldwide (Agras, Ferragut & Abraldes, 2016). Its collective invasion dynamics is characterized by motor actions performed at high intensity and of high technical and tactical demands on players (Barbero-Alvarez et al., 2008; Castagna et al., 2009; Beato, Coratella & Schena; 2016). In this sport, the physical demands are defined by the intermittent character involving the performance of short actions with regard to the distances covered but expressed at high intensity. These actions are manifested in accelerations, decelerations, changes in direction, and sprints followed by short periods of rest (Yeemin, Dias & Fonseca, 2016; Serrano et al., 2020; Soares et al., 2022). Thus, exhaustive muscle contractions, physical contact between opponents and between teammates, and the characteristic handling of the ball configure a situation conducive to the occurrence of oxidative stress and inflammation after training sessions and matches (Borges et al., 2021). In other words, it is a context that imposes a high physiological and neuromuscular demand on the body, and the understanding of this fact is important not only for the understanding of the sport, but also for the consequent appropriate direction of training, either to improve performance, optimize recovery or both (Dal Pupo & Silva, 2022).

Although futsal is a team sport in which everyone is exposed, to a greater or lesser extent, the biological response exhibited may differ from individual to individual. Therefore, monitoring the futsal athlete at all possible times and conditions, during the preparation and competition period, is a critical issue for training,

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which should be contemplated without harming the physical, technical, and tactical preparation, causing no, or the least possible effect. Therefore, there will be situations in which it will not be possible to carry out the desired evaluations. As there is a great variation in the demand for financial resources and time for the tasks that make up athlete monitoring to be carried out, knowledge about physical evaluation, to identify the most appropriate options in both aspects is essential (Santana & Nunes, 2022; David; Duquia. In: Gomes; Costa, 2022).

In the context of high-performance sports, kinanthropometric assessment is of remarkable importance, as it provides information on physical fitness (e.g., body composition, cardiorespiratory, musculoskeletal, and neuromotor fitness), used as a parameter for monitoring performance, training prescription, and training load control (Prestes, Moura & Holpf, 2002; Silva et al., 2018).

Regarding body composition, it is expected that reduced fat mass and/or increased lean mass will lead to higher levels of strength, speed, and power, resulting in better sport performance. Conversely, in the opposite direction, increased fat mass and/or reduced lean mass reduces strength, speed, and power, and elevates both the risk of muscle injury and adverse joint events (Rodrigues et al., 2019). The simple measurement of body weight and height alone, however, does not allow such an estimate to be made to our satisfaction. Therefore, it is necessary to establish adequate composition standards for each sport, and when applicable, adequate standards for each of the possible subdivisions in the same sport, and this standard must be, objectively, a body fat percentage (%BF) below the range in which there is a possible compromise of sports performance (Kenney, Wilmore & Costill, 2020).

In futsal, anthropometric assessment is a doubly indirect method widely used due to its low operating cost, easy application, and validity. This analysis is performed through measurements of height, weight, skinfold thickness, body circumferences, and bone diameters, whose values obtained are used in regression equations developed to predict body density (BD) and, consequently, body fat percentage (BF%) (ACSM, 2014).

Despite many equations available in the literature for this purpose, the equations developed by Jackson and Pollock (1985) to estimate BD draw attention, which, once quantified, allows the use of the Siri equation (1961) to calculate BF% in relation to body mass (BM) (ACSM, 2014). However, there is no consensus on the use of these BD equations in futsal athletes.

Another method used for estimating BF% of futsal athletes is the dual-energy X-ray absorptiometry (DXA). This non-invasive and indirect assessment is considered the “gold standard” for body fat analysis, and it is also a well-recognized parameter for the validation of doubly indirect measurements (e.g., BD equations) (Lázari et al., 2022 Rodrigues et al., 2019). However, the high cost of the device, the low availability in the market, and the fact that it is a laboratory procedure are drawbacks that limit its application – especially in high-performance sports (Queiroga, 2005). Notably, no studies estimating BF% of futsal players by DXA were retrieved.

Thus, the present study aimed to investigate the association between BF% estimated by the “gold standard” indirect method DXA and three different BD equations, in professional male futsal players.

Material & methods

This is an experimental study of cross-sectional design and quantitative approach. Participants were informed about all procedures, and signed the Informed Consent, as recommended by Resolution 466/2012 of the National Health Council and the Declaration of Helsinki. The research was approved by the Institutional Review Board under protocol number 5,557,450.

Sample

The sample consisted of 18 professional male futsal players, adult category, who were participating in the National Futsal League during the 2021 season. The definition of professional futsal player used was the same adopted by Barcelos et al. (2017), namely, athletes working in full-time paid position. The requirement was that they all acted under a contracting regime in line with the current sports labor legislation in Brazil described by Veiga (2018). All procedures were performed in the morning.

Anthropometry

Height and body mass were measured using a wall-mounted stadiometer (Novel Products Inc., Rockton, IL, USA) with 0.5 cm precision and an electronic scale (Toledo 2096PP, São Paulo – Brazil) with 0.5 g precision. Body composition data, other than BF%, were obtained by DXA, as described below.

Body Fat Percentage

The estimation of BF% values by DXA was performed in a densitometer (Lunar DPX-IQ, Wisconsin - USA), using a medium scan mode (sampling rate of 5 mm/s and X-ray current of 750 mA). The quality control of the measurement system was verified daily, with a coefficient of variation (in vitro precision error) less than 0.5. As they were full-body measurements, the athletes remained in the supine position, with the knees extended and close together, and the elbows extended along the body.

To estimate BF% with the three BD equations, skinfold thickness was measured using a Lange caliper (Cambridge Scientific Industries, Inc., Cambridge, Maryland, USA) with a 1 mm scale, and constant pressure of 10 g/mm2. Seven skinfold thicknesses were measured by a single evaluator, in the following order: subscapular

(SE); triceps (TR); chest (CH); midaxillary (MA); suprailiac (SI); abdomen (AB) and thigh (TG). All measurements were performed three times, and the arithmetic mean was considered. The skinfold sites followed the guidelines of the American College of Sports Medicine (2014).

From the skinfold values, it was possible to calculate BD using the three equations proposed and validated by Jackson and Pollock (1985). The first (7SF) estimates BD with the sum of seven SF (SE, TR, CH, MA, SI, AB and TG). The second (3SF1) uses the sum of three SF (CH, AB and TG). The third (3SF2) uses the sum of three SF in a different combination (SE, TR and CH).

After defining BD using each equation described, the respective BF% was calculated using the Siri equation (1961).

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (IBM SPSS, IBM Corporation, Armonk, NY, USA, 25.0). The Shapiro-Wilk test was applied to verify the normality of data distribution. Descriptive analysis consisted of calculating the mean and standard deviation of numerical variables, and the absolute and relative frequencies of categorical variables. To compare BF% estimated by DXA and BD equations, analysis of variance (ANOVA) for repeated measures was used, with Bonferroni correction. Pearson's correlation coefficient was used to verify the presence of correlation between the values obtained by DXA and BD equations, and the results were determined according to Munro (2001) as low (0.26 to 0.49), moderate (0.50 to 0.69), high (0.70 to 0.89), or very high (0.90 to 1.00). Finally, simple linear regression was used to obtain the coefficient of determination. For all tests, a value of $p < 0.05$ was considered statistically significant.

Relative reliability was determined from the intraclass correlation coefficient, classified according to Koo and Li (2016) as poor (less than 0.5), moderate (0.5 to 0.75), good (0.75 to 0.9), or excellent (greater than 0.9). To estimate the absolute reliability, we used the standard error of measurement and the systematic error; and the Bland-Altman plot method to demonstrate trends and systematic errors, with confidence limits calculated as the difference between the means and standard deviation of 1.96

Results

The mean age of the sample was 21.11 ± 3.18 years. There were 83% right-handed and 17% left-handed players. Regarding the tactical position, 17% were goalkeepers, 22% defenders, 50% wingers, and 11% pivots. Table 1 displays the anthropometric characterization of the sample.

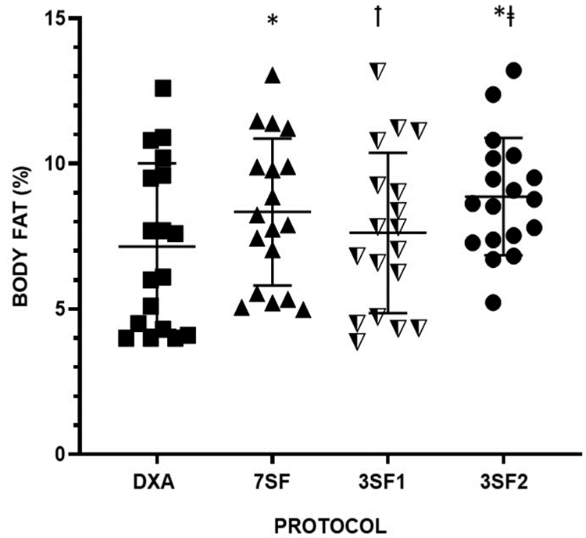
Table 1, Anthropometric characterization of the sample (n=18)

	Minimum	**Maximum**	**Mean ± SD**
Body mass (Kg)	55.71	81.29	71.23 ± 7.27
Height (m)	1.67	1.85	1.76 ± 0.06
BMI (Kg/m²)	19.79	26.16	22.95 ± 1.83
BFM* (Kg)	2.32	9.69	4.92 ± 2.27
LBM* (Kg)	50.12	69.29	62.61 ± 5.78
BM* (Kg)	2.88	4.27	3.70 ± 0.39
BMD* (g/cm³)	1.24	1.50	1.37 ± 0.07
BF%			
DXA (%)	4.00	12.60	7.15 ± 2.87
7SF (%)	4.98	13.05	8.34 ± 2.53
3SF1 (%)	3.87	13.17	7.62 ± 2.76
3SF2 (%)	5.22	13.21	8.87 ± 2.02

Abbreviations: BMI = Body Mass Index. BFM = Body Fat Mass. LBM = Lean Body Mass. BM = Bone Mass. BMD = Bone Mineral Density. BF% = Body Fat Percentage. DXA = Dual-Energy X-Ray Absorptiometry. 7SF = Seven skinfolds. 3SF1 = Three skinfolds 1. 3SF2 = Three skinfolds 2. *Values estimated by DXA

BF% obtained by 7SF and by 3SF2 were higher than the values estimated by 3SF1 and DXA ($p < 0.01$ on all occasions). There was no significant difference between 7SF and 3SF2, as well as between 3SF1 and DXA (Fig.1).

Fig.1, Comparison of body fat percentage estimated by DXA and 7SF, 3SF1 and 3SF2 (n=18)



Notes: P-value obtained by analysis of variance ANOVA for repeated measures. * ($P < 0.05$) in relation to DXA. ƚ ($P < 0.05$) in relation to 7SF. ł ($P < 0.05$) in relation to 3SF1.
The BF% calculated by BD equations revealed positive correlations from high to very high with BF% estimated by DXA, as shown in Table 2, which also includes the coefficient of determination of each equation.

Table 2 - Correlation and determination coefficients between body fat percentage estimated by DXA and 7SF, 3SF1 and 3SF2 (n = 18).

	r	r^2	*p*
7SF	0.926	0.849	< 0.01
3SF1	0.924	0.844	< 0.01
3SF2	0.867	0.737	< 0.01

Abbreviations: DXA = Dual-Energy X-Ray Absorptiometry. 7SF = Seven skinfolds. 3SF1 = Three skinfolds 1. 3SF2 = Three skinfolds 2.

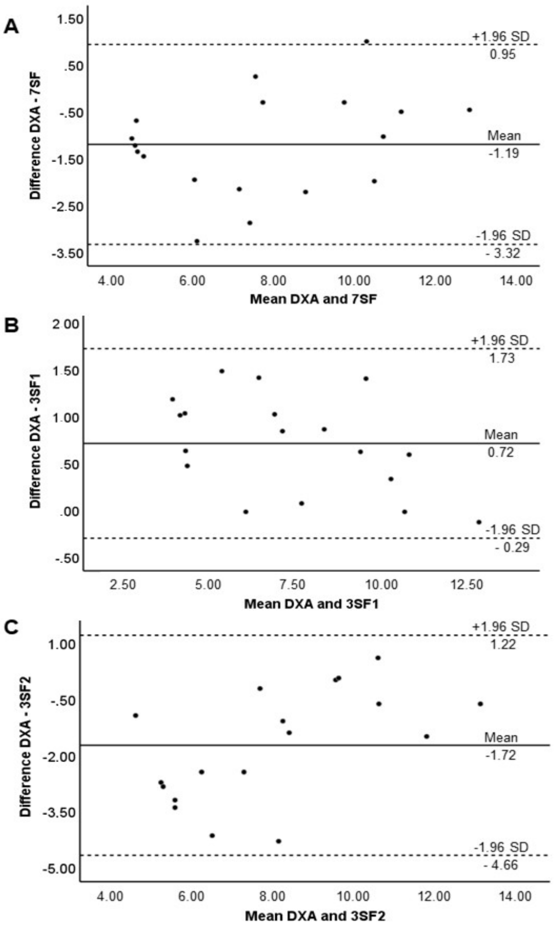
The absolute and relative reliability data for each BD equation are depicted in Table 3. The findings indicate that relative reliability was good for 7SF, excellent for 3SF1, and moderate for 3SF2.

Table 3, Absolute and relative reliability of 7SF, 3SF1 and 3SF2 in relation to DXA (n=18)

	ICC*	SEM	SE
7SF	0.842 (0.199 – 0.955)	1.09	- 1.19 ± 1.09
3SF1	0.914 (0.779 – 0.967)	0.52	0.72 ± 0.52
3SF2	0.665 (-0.017 – 0.891)	1.50	- 1.72 ± 1.50

Abbreviations: DXA = Dual-Energy X-Ray Absorptiometry. 7SF = Seven skinfolds. 3SF1 = Three skinfolds 1. 3SF2 = Three skinfolds 2. ICC = Intraclass Correlation Coefficient. SEM = Standard Error of Measurement. SE = Systematic Error. *Confidence interval in parentheses.

Bland-Altman plots are illustrated in Fig. 2.



Dicussion

This study aimed to investigate the association between BF% estimated by the "gold standard" indirect method DXA and three different BD equations, in professional male futsal players. The results revealed a BF% not only lower than the reference value for the general population of the same age group (24.8%), proposed by Ofenheimer et al. (2020), but also lower than the reference value for male athletes (13.9%), described by Santos et al. (2014).

The findings showed that BF% predicted by the three BD equations are correlated with the value obtained by DXA, which is high for 3SF2, and very high for 7SF and 3SF1. Walker et al. (2022), who evaluated male professional soccer players and Australian football players, also identified a large correlation with the sum of seven skinfolds in the preparatory, competitive and transition phases.

Suarez-Arrones et al. (2018) investigated male professional soccer players, in the competitive period, and identified a strong positive correlation with the equations of Faulkner (1968), Eston et al. (2005), Durnin and Womersley (1974), and Withers et al. (1987); a moderate correlation with the equations of Yuhasz (1962), Oliver et al. (2012) and Reilly et al. (1996); and a low correlation with the Deurenberg, Westrate & Seidell (1991) equation. In turn, Petri et al. (2020) evaluated male professional soccer referees during a competitive season and found a positive correlation with the equations of Yuhasz (1962), Faulkner (1968), Durnin and Womersley (1974), Reilly et al. (1996), and Suarez-Arrones et al. (2018), and a moderate correlation with the equation developed by Eston et al. (2005).

The presence of a strong or moderate correlation between BF% estimated by DXA and different equations was also reported in studies in which the periodization was not identified. Lázari et al. (2022) evaluated male professional sprinters using four distinct equations: Faulkner (1968), Slaughter et al. (1988), Boileau, Lohman & Slaughter (1985) and Lázari (2017). The authors found a strong correlation between data obtained by DXA and Faulkner's predictive equation and a moderate correlation with Slaughter et al. equation. No statistically significant correlation was observed for the equations of Boileau et al. (1985) and Lázari (2017). The age group and the consequent competitive category also do not seem to nullify this phenomenon. Gomes et al. (2020) conducted a cross-sectional study with athletes of both sexes, from various sports and categories, and reported that the sum of seven skinfolds presented a high positive correlation with the adjusted body fat (g/kg) measured by DXA in the two middle quartiles, and moderate in the highest and lowest quartiles.

Nevertheless, despite the aforementioned correlations, BF% calculated by 7SF and 3SF2 differed significantly from that obtained by DXA, overestimating such value. Ploudre et al. (2018) also observed strong or moderate correlations between BF% estimated by DXA and equations, even with significant differences between the values. However, unlike us, the authors reported that the equations underestimated BF% obtained by DXA in the sample of college women basketball players, either with the Jackson, Pollock and Ward (1980) equation or with that of Mayhew et al. (1985), in the preparatory, competitive and transition phases, or with the Durnin-Womersley formula in the competitive season.

Prior studies suggest that BF% estimated by DXA also seems to be underestimated by equations when periodization is not identified, be it in individual sports, be it in adapted team sports, as in the case of Pineau and Frey (2015) investigating female elite judokas through the equation defined by Warner et al. (2004), and with men, professional wheelchair basketball and wheelchair rugby athletes, evaluated by Goosey-Tolfrey et al. (2016) with the sum of eight skinfolds.

The BF% obtained by 3SF1, besides presenting a strong correlation with the value estimated by DXA, did not differ significantly from it. This is possibly due to the thigh SF, because it is only one of six other SF in 7SF, and it is not a part of 3SF2. According to Eston et al. (2005), thigh SF has the highest correlation with BF% calculated by DXA, which may explain 79% of the variation. This perception seems to be common to Eston (2003), who in an interesting editorial published in the Journal of Sports Sciences, describes about the relevance of lower limb SF sites to predict BF%, as well as to the steering group of the British Olympic Association, which suggests its use, as reported by Reilly et al. (1996).

The 3SF1 equation also showed the highest relative reliability and the best absolute reliability. In our sample, this equation yielded a lower standard error, a comparable intraclass correlation coefficient, and a coefficient of determination comparable or better to cases in which a skinfold equation was used specifically in the group of athletes for which it was developed, as the equations proposed by Petri et al. (2020) for male elite soccer referees (SEM = 2.62; r^2 = 0.61), by Goosey-Tolfrey et al. (2016) for male elite wheelchair basketball and wheelchair rugby athletes (SEM = 2.78; r^2 = 0.84), and by Cavedon et al. (2018) for female professional handball players (SEM = 2.00; ICC = 0.993; r^2 = 0.88). Therefore, the use of 3SF1 for professional male futsal athletes is strongly recommended.

Despite the promising result of 3SF1 obtained in our study, only one previous work investigated professional futsal athletes using this formula. Nunes et al. (2012) identified 12.3% of body fat in a sample evaluated during the competitive phase. Although these players are of a similar level, of the same modality, and in the same periodization, they presented a BF% more than 60% higher than that observed in our sample.

Most of the literature we reviewed focused on the use of 7SF, and through this equation, our sample showed a BF% lower than those obtained in other similar studies. Avelar et al. (2008) reported 9.4% of body fat in professional futsal players during the competitive phase, and Gomes et al. (2011), 12.32%. Although Soares-Caldeira et al. (2014) also used 7SF, the authors considered the equation defined by Brozek et al. (1963) to estimate BF%, instead of the Siri formula, recommended by Jackson and Pollock (1985). In this study, the players were randomly assigned into two groups, and BF% was 9.38% and 8.77%, in the competitive phase, and 13.01% and 12.29%, respectively, in the preparatory phase.

The only exception is the casuistry of Zeferindo and Sene (2010), who reported a body fat of 6.90% during the training phase. Apparently, the lower BF% could be because the team was on eve of competing in a continental championship, probably coming from a strenuous sequence of training and competitions that qualified them for the international tournament, thus suggesting a high sustained energy expenditure over a considerable space of time. Indeed, during the preparatory phase, the athletes already had, on average, 8% body fat, a value nominally lower than those observed in all previous studies.

To the best of our knowledge, there is no previous study analyzing professional futsal players using 3SF2. This fact is possibly due to the suggestion of Jackson and Pollock (1985) who, despite having proposed both 3SF1 and 3SF2, recommend only the use of 3SF1.

Studies carried out with elite level futsal players during a competitive phase using Faulkner's equation are also available in the literature. Barcelos et al. (2017) recorded a BF% of 11.84%, and Campos et al. (2009), 12.34%. In both cases, BF% is nominally lower than our sample. In the preparatory phase, as expected, the values were nominally higher, totaling 11.9% in the sample of Barcelos et al. (2017) and 15.11% in the sample of Campos et al. (2009).

Using the sum of eight skinfolds, Spyrou et al. (2021) reported 9.28% body fat in the competitive phase, and 9.29% in the preparatory phase. Garrido-Chamorro et al. (2012), by the sum of seven skinfolds, determined a BF% of 15.1% in elite futsal athletes, but without specifying whether they were evaluated in the same phase and, if so, in which one.

There are also studies performed with professional futsal athletes in the competitive phase that did not inform the equation used, such as Floriano et al. (2006), who reported 14.1% body fat for the team, and Nogueira et al. (2020) reported 11.6%. In some cases, this may be due to the fact that BF% is just a sample characterization parameter, and not a dependent variable to be analyzed, as Moura et al. (2013), who identified 10% body fat in defenders and pivots, 11% in wingers, and 13% in goalkeepers. A similar result was found by

Oliveira et al. (2019), whose average BF% of the sample was 9.3%, and Oliveira et al. (2019) reported 9.3% in their evaluation.

In continuity, some studies also evaluated professional futsal athletes using bioimpedance. Parpa and Michaelides (2022) observed a %GC of 16.3% at the beginning of the preparation period. In the competition period, Iedynak et al. (2019) reported 13.4%, and Sánchez-Sánchez et al. (2018), 13.1%. Amani-Shalamzari et al. (2019), on the other hand, reported 2.8%, but without objectively specifying the periodization phase. In turn, Alkoot et al. (2019), who collected the data in random periods, describe an average value of around 9%.

Conclusions

Considering the relevance of futsal in the current sports scenario, and taking into account the demands and specificities presented, with special attention to the widespread use of the estimate of BF% by means of skinfolds, as well as the limitations of the use of DXA. The three equations used estimated a BF% that correlated with that estimated with DXA, especially 7SF and 3SF1, whose correlation was very high, since with 3SF2 it was high. On the other hand, 7SF and 3SF2 differed significantly, for more, from the "gold standard" estimate, while 3SF1 did not. Thus, in the context of the practical application of these findings, it is plausible to recommend that 3SF1 be used to estimate BF% in professional male futsal athletes in the competition period.

It is pertinent that future studies seek to replicate the analyses presented here in different periods and in larger samples, allowing the comparison of teams from different competitive levels and different locations, making subdivisions regarding goalkeepers and line players' positions. In such circumstances, it would also be interesting to verify possible relationships not only with DXA, but with technical, tactical, and physical performance metrics. And, especially, samples that allow, numerically, to elaborate equations and classifications specific to futsal.

Moreover, it is important that both the procedures performed in this study and those suggested above be done in other categories, such as master, and especially in different youth categories, in both sexes.

Last but not least, it is worth mentioning that the assessment of the present study should be made taking into consideration its methodological limitations, such as sample size, the coverage of a single team in a single period, and the potentially dubious character of a BF% lower than that of most reports available in the scientific literature on the subject.

Conflicts of interest - We declare the absence of conflicts of interest.

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