Validation of anthropometric equations for the estimation of body density in professional soccer players

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ABSTRACT

The objective of this study was to validate equations which estimate the body density in professional soccer players. Twenty-five soccer players were evaluated, aged 22.7 ± 4.4 years, body mass 73.9 ± 6.6 kg, and height 177.8 ± 5.5 cm, who played in the state championship of the Federação Gaúcha de Futebol in 2004. The validity of 11 anthropometric equations were analyzed by the process: Pearson correlation (r), dependent *t* test, constant error (EC), total error (ET) and estimated standard error (EPE), using hydrostatic weight as the "gold standard". In the current study of 11 equations, only the equations proposed by Jackson and Pollock (1978) are valid for estimating the body density of professional soccer players, since the other equations analyzed in this study present considerable errors in their estimation.

Keywords: Anthropometric. Validation. Equations.

INTRODUCTION

High performance sports demand constant improvement of knowledge level on their intervenient variables (morphological, physiological, psychological, biomechanical, and cognitive among others). Soccer, due to its specific condition, involves a high number of athletes and is played in different climate conditions, with technical, tactical and physical varied alternatives, becoming hence a sport of high complexity of interpretation and study.

Under the perspective of this set of variables, body composition assessment represents one of the important identification elements of the soccer player profile.

Works published in journals which describe morphological characteristics of soccer athletes in its majority make use of a method called anthropometry. Such method uses measurement quantification in the study of size, shape, proportionality, composition and maturation of the human body[1]. After obtaining the measurement values, these are applied in equations and, via calculations, it is possible to fractionate the human body composition in fat, muscular, bone and residual mass through the analysis of the relative value in percentage with the total body fat value. Such outcome is usually analyzed by technicians.

In order to make use of an equation in a given population, it is necessary that this equation has reached scientific criteria in the evaluated population, that is, it should be valid to measure what it is proposed to measure, or else, it can underestimate or hyper estimate values, adding an assessment error, which leads to misleading diagnosis, prescription and training control[2-5].

It is observed that in Brazil, both in professional soccer practice and in the academic field, equations coming from samples of foreign athletes or national generalized equations have been systematically used. In other words, equations which have used a wider sample for elaboration, which probably will imply in an evaluation error[2,4,6]. Thus, soccer coaches should have as reference a specific equation which considers these athletes' characteristics.

Once this methodological issue has been identified, the study had as aim to analyze the validation of the anthropometric equations for body density estimation in professional soccer athletes.

METHODS

The studied group consisted of professional soccer athletes (n = 25) mean age 22.7 ± 4.4 years and between 18 and 32 years, with a minimum of 2 months of training and 4 hours of daily training, comprised in the competition season promoted by the Soccer Federation of Rio grande do Sul State, year of 2004.

The anthropometric measurements were taken[7] with adaptations, respecting the measurement procedure concerning validation of the original equation, in which the analyzed measurements were: body mass (BM) and height (H), with the use of a scale and stadiometers (RIW 200, Welmy, Brazil). The measured perimeters were the ones from the forearm (FA P.) and abdomen (AB P.), with a measuring tape (Cescorf Científico, Cescorf, Brazil). For the skinfolds, the chosen registers were: triceps (TR. SF), biceps (BI. SF), subscapular (SS. SF), chest (C.SF), media underarm (MUA SF), supra- iliac (SI. SF), horizontal abdominal (ABh. SF), vertical abdominal (ABv SF), medium thigh (MT SF) and medium leg (ML SF), measured with the skinfold dividers (Cescorf Científico, Cescorf, Brazil).

The anthropometric procedures adopted were the following: a) for all measurements, the right side of the athlete was adopted; b) the measurement was conducted in a rotation system with three measurements, being the mean taken as final measurement. These measurements were taken by a single evaluator, c) the non-performance of training physical activities at least for 4 hours prior to the data collection, d) checking of the used instruments as well as the room temperature where collection would take place, which was standardized between 24°C and 26°C for all assessments. In addition to the previous procedures, e) the trustworthiness in the measurements of the single evaluator involved in the data collection was also tested.

The value of the hydrostatic weighing (HW), gold standard method, was obtained with the use of a 1 meter and 50 centimeters high tank and had the aid of two evaluators: on inside the tank, who helped and explained to the volunteer the testing methodology, and another who performed the scale reading (Filizola L, Filizola, Brazil) which had 5 grams resolution and 6 kg capacity. The volunteer was wearing a bathing suit during the measuring. Grouped position[8] was used as submersion position of the individual in water, and he was motivated to eliminate all the air kept in the lungs and air ways through expiration.

Breathing was kept blocked for approximately 5 to 10 seconds, for scale's stabilization, when the weighing reading was then recorded. This same procedure was repeated 6 to 10 times. The mean of the three last highest readings was used as hydrostatic

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weighing value. Whenever the values of the three last readings diverged in more than 50 grams, additional weighing was performed and all obtained values in the readings were recorded. Water temperature was standardized at 31°C for all evaluations and measured with the aid of a thermometer (Incoterm, Brazil). Besides the temperature, it was tried to control whether the volunteers had performed physical activities and intaken ant kind of meal before the evaluation. The used instruments were also checked.

The residual volume (RV) was obtained through the equation[9]:

Men ⇒ RV = 0.017 (age, years) + 0.027 (height, cm) – 3.477

After the hydrostatic weight and residual weight check, the values were applied in the equation which determines body density.

$$D(g/cm^3) = \frac{P}{[(W - Ww)/Wd] - (RV + 0.1)}$$

Where:
D = Body Density, in g/cm³;
W = Body Mass in kg on air;
Ww = weight in water in kg;
Wd = Water density (corrected by the temperature);
RV = residual volume, liters;
0.1 = gastrointestinal gas constant (100 ml).

The evaluation procedures were performed in the following stages: first, the aim of the study, the methodological procedures to be developed as well as the authorization of the Ethics in Research Committee were presented to the athletes. Later, the athletes read the consent form and after having agreed on all items, they signed an agreement form as research subjects. The evaluations were performed in the Cine Anthropometry, Measurements and Evaluation Laboratory, situated at the Santa Maria Federal University, in the Rio Grande do Sul State.

Data collection was first performed with the anthropometric measurements and later the individual was taken to the tank where the hydrostatic weighing occurred (HW).

Table 1 presents the list of the 11 equations proposed by several authors and which will be analyzed in this study. Table 1 also shows sample's age, correlation value and estimated standard error in the original validation studies.

Statistical analysis followed these procedures: first, the data normality was tested through the Shapiro-Wilk test, and it detected the need for parametric statistics[17]. In order to analyze trustworthiness, which consists of results reproducibility from the part of the evaluator, a pre-test and post-test evaluation and their results were verified through the statistical process correlation moment by Pearson as well as dependent "t" test with significance level of $p < 0.05$. Descriptive analysis was used for validation of equations, which consists of mean results (X), of the standard deviation (s), of the minimum value (Min), of the maximum value (Max) and the variation coefficient (VC), besides the validation criteria[18]: Pearson correlation (r), dependent "t" test, constant error (CE), total error (TE) and estimated standard error (ESE), being all analyzed in the statistical program SPSS 8.0 *for Windows*.

RESULT

The outcomes obtained in this study are presented in tables. Table 2 presents the descriptive characteristics of the group of athletes studied, including the data of hydrostatic weighing, skinfolds and perimeter data. Table 3 presents the outcomes of the validation criteria of the 11 equations.

The test and re-test values showed high reliability from the part of the evaluator, both for the Pearson correlation and the dependent "t" test, being all values statistically significant ($p < 0.05$). These results guarantee the trustworthiness of the values obtained through anthropometry and densitometry, allowing hence the evaluation of the group of athletes studied.

TABLE 1
Reference, equations, sample age, correlation value and original estimated standard error of the equations used for validation

Reference	Equation	Age (year)	r	ESE
1. Durnin and Rahman, 1967	1.161 – 0.0632 * LOG10 (BI SF + TR SF + SS SF + SI SF)	18-34	0.83	0.0069
2. Sloan, 1967	1.1043 – 0.001327 * (MT SF) – 0.00131 * (SS SF)	18-26	0.84	0.0067
3. Forsyth and Sinning, 1973	1.103 – 0.00168 * (SS SF) – 0.00127 * (AB SF)	19-22	0.82	0.0060
4. Katch and McArdle, 1973[10]	1.09665 – 0.00103 * (TR SF) – 0.00056 * (SS SF) – 0.00054 * (AB SF)	18-24	0.86	0.0072
5. Durnin and Womersley, 1974[11]	1.1765 – 0.0744 * LOG (TR SF + SS SF + SI SF + BI SF)	17-72	–	0.0103
6. Lohman, 1981[12]	1.0982 – 0.000815 * (TR SF + SS SF + AB SF) + 0.0000084 * (TR SF + SS SF + AB SF)²	–	0.92	0.0071
7. Thorland *et al.*, 1984[13]	1.1136 – 0.00154 * (TR SF + SS SF + MUA SF) + 0.00000516 * (TR SF + SS SF + MUA SF)²	14-19	0.81	0.0056
8. Guedes, 1985[14]	1.17136 – 0.06706 * LOG (AB SF + SS SF + TR SF)	17-27	0.89	0.0057
9. Petroski, 1995[15]	1.09255357 – 0.0006798 * (TR SF + SS SF + SI SF + PM SF) + 0.00000182 * (TR SF + SS SF + SI SF + PM SF)² – 0.00027287 * (ID) + 0.00204435 * (FA.P) – 0.00060405 * (AB.P)	18-66	0.88	0.0071
10. Jackson and Pollock, 1978[16]	1.112 – 0.00043499 * (C.SF + MUA.SF + TR SF + SS SF+ AB SF + SI SF + MT SF) + 0.00000055 * (C SF + MUA SF + TR SF + SS SF + AB SF + SI SF + MT SF)² – 0.00028826 * (ID)	18-61	0.90	0.0078
11. Jackson and Pollock, 1978[16]	1.10938 – 0.0008267 * (C SF + AB SF + MT SF) + 0.0000016 * (C SF + AB SF + MT SF)² – 0.0002574 * (ID)	18-61	0.90	0.0077

Source: equations 4, 5, 6, 7, 8, 9, 10 and 11 original articles; equations 1, 2 and 3 extracted from Petroski (1995).

TABLE 2
Descriptive characteristics of the group of professional athletes, used in the validation of the equations which estimates body density (n = 25)

	Mean	s	Variation	VC(%)
Age (years)	22.7	± 4.4	18-34	–
Time of practice Soccer professional (years)	6.0	± 4.2	1-14	–
Body mass (BM) (kg)	73.9	± 6.6	57.0-86.4	9.25%
Height (H) (cm)	177.8	± 5.5	165.0-186.0	3.05%
Hydrostatic weighing (HW) (kg)	4.3	± 0.6	2.7-5.3	14.60%
Body density (BDm) (g/cm³)	1.0833396	± 0.005922	1.0684-1.0931	0.55%
Skinfolds (mm)				
Tricipital (TR SF)	8.0	± 1.8	5.3-10.8	23.41%
Bicipital (BI SF)	3.7	± 0.5	3.1-4.8	12.99%
Subscapular (SS SF)	11.7	± 2.6	8.0-18.3	23.40%
Supra-Iliac (SI SF)	13.5	± 4.6	7.5-28.4	35.79%
Medium underarm (MUA SF)	9.4	± 2.7	6.3-17.4	29.52%
Chest (C SF)	5.9	± 1.6	3.7-10.2	27.22%
Horizontal abdominal (ABh SF)	13.6	± 6.0	6.5-31.4	44.38%
Vertical abdominal (ABv SF)	12.4	± 6.3	5.5-32.2	51.59%
Medium thigh (MT SF)	10.1	± 3.4	6.0-18.5	34.35%
Medium leg (ML SF)	6.1	± 1.4	3.7-9.6	24.68%
Perimeters (cm)				
Forearm (FA P)	27.0	± 1.2	24.0-29.5	4.75%
Abdomen (AB P)	80.0	± 3.5	73.0-88.0	4.55%

BDm = body density measured by hydrostatic weighing.

TABLE 3
Results of the validation criteria of the equations

Equation	Mean	s	T test	Correlation	CE	TE	ESE
PH	1.0833396	0.005922	–	–	–	–	–
EQ1	1.0622562	0.005949	21.724(0.000)	0.67(0.000)	–0.021083	0.02159	0.003276
EQ2	1.0752242	0.007317	6.343(0.000)	0.56(0.004)	–0.008115	0.01017	0.005057
EQ3	1.0671087	0.011550	9.895(0.000)	0.76(0.000)	–0.016231	0.01804	0.004996
EQ4	1.0749554	0.006186	9.691(0.000)	0.75(0.000)	–0.008384	0.00935	0.002712
EQ5	1.0602567	0.007002	21.456(0.000)	0.67(0.000)	–0.023083	0.02365	0.003857
EQ6	1.0813496	0.002148	2.039(0.053)	0.66(0.000)	–0.001990	0.00509	0.001235
EQ7	1.0728746	0.007886	8.914(0.000)	0.68(0.000)	–0.010465	0.01188	0.004256
EQ8	1.0698421	0.009483	9.670(0.000)	0.69(0.000)	–0.013497	0.01507	0.004990
EQ9	1.0682713	0.006970	13.732(0.000)	0.66(0.000)	–0.015068	0.01596	0.003992
EQ10	1.0808771	0.008581	2.032(0.054)	0.72(0.000)	–0.002463	0.00631	0.004190
EQ11	1.0854650	0.008359	–1.771(0.090)	0.71(0.000)	+0.002130	0.00614	0.004229

EQ = Equation; SE 0 Standard error; TE = Total error; ESE= estimated standard error.

DISCUSSION

The found results for body mass and height are normal when compared with the results of other national[6,19-25] and international athletes[4,26-33], being lower than in the study with athletes from Yugoslavia[34] and professional athletes from Iceland[35] and Germany[29].

Comparing the skinfold values with studies involving national athletes, these do not present remarkable difference when compared with athletes from Paraíba[6] and Santa Catarina states, and are similar to the athletes from Rio Grande do Sul state[20]. Such similarity is probably due to the fact that the group studied is from the same region.

Body density values in most of the equations studied presented higher results than the ones from their original validation studies, except for the EQ2 and EQ5 equations, which presented similar values, and for EQ1, which obtained result below the results found in its original study.

When analyzing validation criteria, they reveal that the EQ6 equation hyper estimates body density of the subjects below the mean and underestimates body density of the subjects above the mean, once its values of standard deviation are lower than the ones of the hydrostatic weighing, an outcome similar to the one found in a study with soccer athletes from the sub-20 category[36]. In the EQ1, 2, 3, 4, 5, 7, 8, 9, 10 and 11 equations the opposite fact occurs; they underestimate body density of the subjects below the mean and hyper estimate body density of the subjects above the mean, since its values of standard deviation are higher than the body density measured by hydrostatic weighing.

The second validation criterion, the "t" test, showed that only the EQ6, 10 and 11 equations do not differentiate from the standard measurement, while all the remaining presented statistical differences. The equations have reached moderate correlations and the highest value was obtained by an equation (EQ3) which had as validation group athletic individuals.

The correlation values behaved fairly below the original validation studies (table 1), and not even the EQ3 and EQ7 equations, which used athletes in their building process, repeated the same values.

Constant error (CE), which is the subtraction of the body density measurement estimated by the body density measured through hydrostatic weighing, shows that, except for the EQ11, which presents positive value, the remaining presented lower values of body density than the standard method. It is important to highlight that for the constant error (CE) and the estimated standard error (ESE), the lower its measurement; the higher the safety will be affected by the sample's variability.

When the CE is analyzed, one can note that the EQ4, 6, 10 and 11 equations obtained the lowest values, while for ESE an index around 0.0098 g/cm³ was chosen in relation to the mean, which corresponds approximately to 4% of body fat, as an accuracy threshold with which the body density values would be predicted through anthropometric variables[12]. In the present study, all used equations presented measurements lower than this cutting point and it had its values lower than the values from original studies. A hypothesis for this result would be a small number of analyzed individuals as well as by the homogeneity of their measurements.

CONCLUSION AND RECOMMENDATION

In an attempt to answer the aim of this study to analyze the validation of anthropometric equations in the estimation of body density in professional soccer athletes, it is concluded that:

In the present study, from the 11 equations analyzed, only the equations proposed by Jackson e Pollock (1978), EQ10 and EQ11, respectively from seven and three skinfolds, responded to the validation criteria, having moderate correlation with the hydrostatic weighing used as gold standard measurement, though.

The preference over the equation of three skinfolds is recommended in the performance of the body density assessment in professional soccer athletes, once it is practical and maximizes the evaluators' time.

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