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Comparison between plethysmography and body fat equations in elite taekwondo athletes

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Abstract
Background. In taekwondo, body composition and body fat percentage (BF%) are decisive factors in the result of combat between elite athletes. In recent years, air displacement plethysmography (ADP) has appeared as a reference method to evaluate BF%, while skinfold-based equations can be used in those cases in which people are unable to access such equipment.
Problem and Aim: To determine the degree of agreement between the BF% estimated by the ADP method and by different skinfold-based equations in male taekwondo athletes.
Methods. 12 elite Brazilian male athletes (19.5± 3.8 years old) were evaluated using the *International Society for the Advancement of Kinanthropometry* (ISAK) protocol. BF% was estimated using 9 skinfold-based equations whose results were compared with those of the ADP method.
Results. The mean of the BF% measured using the reference method was 8.9 ± 5.4. Agreement between skinfold based equations and ADP methods was examined by the Bland-Altman method. The narrowest limits of agreement relative to the reference were for the Katch & McArdle skinfold-based equation (−5.5, 5.9) containing 95% (11/12) of the score difference. The mean difference (bias) of the measurements between ADP and the anthropometric methods was (0.18±2.9).
Conclusions. These results suggest that the Katch & McArdle equation, applying body density from the Brozek *et al* equation. [1963], could be considered the most appropriate method to determine BF%, as its results are closest to those established by the ADP method. This equation presents good repeatability and concordance, small percentage error, and ease of use in the body fat evaluation of taekwondo athletes.

Introduction

Taekwondo is a thousand-year-old fighting art from Korea, actually practiced by 60 million people in more than 180 countries around the world. The reputation of taekwondo enhanced since its apparition as an Olympic sport in 2000. This recognition led to various changes in the rules and specificities of the combat [Kazemi, Pieter 2004b]. This martial art sport involves the delivery of explosive and powerful movements within a short period of time. Taekwondo is actually practiced using a differential point scoring system, with combats consisting of 3 rounds of 2 minutes each, with a 1-minute rest period [Kazemi, Casella, and Perri 2009a; Kim *et al.* 2015b; Wazir *et al.* 2019].

Performance in taekwondo is determined by a large variety of parameters including technical, tactical, psychological and physiological [Pieter, Heijmans 2003]. More particularly, parameters of body composition (body mass) play a major role in martial arts [Monterrosa, Moro 2020]. Indeed, as a weight division game and due to the actual scoring system, players whose profiles are relatively tall, with low body fat percentage and high fat-free mass are favorable to performance, and are usually observed in the best taekwondo athletes [Fong, Yin Fat 2011; Kim *et al.* 2011a; Campos *et al.* 2012].

Thus, it is primordial to be able to assess body composition in the athletic population to optimize performance and determine specific nutritional interventions. To ensure this challenge and evaluate the body composition (especially body fat percentage) of athletes, skinfold (SF) measures are a widely employed method due to its accessibility, facilities, and low-cost requirement [Monterrosa *et al.* 2019]. However, numerous equations relative to this measure have been developed, all with a specific population applicability [Norgan 2005]. Thus, some limitations must be taken into account in order to generalize and compare the results obtained through the SF method: specific population, evaluation protocols, influence of the evaluator, and type of equations employed to calculate percentages of body mass [Bridge *et al.* 2014; Grove, Hung 2017]. To override these limitations, air displacement plethysmography (ADP), another scientifically validated densitometric method, which has been considered a reference to evaluate human body composition and the underlying body fat percentage [Pieter, Heijmans 2003].

ADP evaluates body volume by measuring the reduction in chamber volume caused by the introduction of a person into a chamber with a fixed air volume [McCrory *et al*. 1995]. This method requires the use of a full body plethysmograph, such as the "Bod Pod" fiberglass chamber that uses air displacement and pressure-volume ratios to measure body volume. The Bod Pod system consists of two chambers: a front chamber in which the subject sits during the measurement and an empty chamber. Body volume is calculated as the difference between the volume of the chamber when it is empty and when the subject is sitting inside [McCrory *et al.* 1995; Dempster, Aitkens 1995; Biaggi *et al.* 1999]. ADP demonstrates good correlations with other techniques such as DXA (dual-energy X-ray absorptiometry), electrical bioimpedance, and hydrostatic weighing [Levenhagen *et al.* 1999].

In the field of taekwondo athletes, the review of Bridge *et al.* [2014] presented values of body fat percentage of taekwondo players, reporting 42 references in which the majority used the SF measurements. However, the prediction equations used to calculate body fat with this method were diverse. In this context, the development of a reliable and valid prediction equation remains to be determined. Besides, considering plethysmography as a new reference to predict body fat percentage, it would be an interesting approach to compare the results obtained through this method with those observed using the different equations from skinfold measures, to provide reliable body fat measurement alternatives for taekwondo coaches. As there is no clear recommendation for a field method to assess body composition in elite taekwondo athletes, the aim of our study was to compare the results of the body fat percentage in a group of high-level taekwondo athletes obtained with different equations of the SF method with the ADP technique.

Material and Methods

Participants

Twelve elite male taekwondo athletes were recruited from various sports academies of the state of Santa Catarina (Brazil), with the support of the Brazilian Taekwondo Federation. The prerequisites to participate in this study were to be a competitor athlete with national or international experience, without any injury and currently training.

Participants fulfilling these criteria were informed about the evaluation process and of its possible risks. Data collection was conducted in one day from 7:00 to 9:00 am. The athletes took part in the evaluation with ADP and then in the anthropometric exam. All morphological characteristics of the participants are presented in Table 1.

Table 1. Morphological characteristics of the athletes.

	Mean ± SD	Range
Age (years)	19.5 ± 3.8	16 – 30
Height (cm)	177.4 ± 4.2	172.5 – 184
Body mass (kg)	70.7 ± 9	57.7 – 84.9
Body fat (%) *	8.9 ± 5.4	4.1 - 19
Skinfolds (mm)	–	–
Biceps	3.6 ± 0.9	3 - 5
Triceps	6.4 ± 2.6	4 - 12
Subscapular	8.6 ± 3.4	6 - 17
Chest	6.0 ± 2.3	5 - 13
Suprailiac	10.5 ± 4.3	7 – 21.5
Supraspinal	6.4 ± 2.8	4 - 14
Abdominal	13.2 ± 6.4	6 - 26
Front thigh	10.5 ± 4.3	7 – 22.5
Calf	6.8 ± 3.5	4 – 6.5

Note: * Body fat characteristics were measured using ADP; SD: standard deviation; cm: centimeter; kg: kilogram; %: percentage; mm: millimeter.

Before their evaluation process, all participants signed the informed consent document relative to the Declaration of Helsinki, approved by the ethics committee of the Federal University of Santa Catarina (Brazil).

Procedures and measures

Anthropometric measurements: after body mass and height measurements, the anthropometric evaluation

was performed by a certified anthropometrist (certified level 2 by the *International Society for the Advancement of Kinanthropometry*). The protocol used was the complete profile composed of 43 body measures:
I. Skinfold (9)
II. Body measures (4) including body mass, stature, sitting height, and wingspan
III. Girths (13)
IV. Breadths (9)
V. Lengths (8)

Every measure was performed on the right side of the athletes twice at the same point. In the event that we had a variation greater than 5% for the SF measures and 2% in the bone diameters, a third measure was realized. The objective of this evaluation was to determine the body composition of the subjects, including the determination of the fat-free mass and fat mass components. To realize the overall of the previously mentioned measures, we used the following devices: adipometer, sliding caliper, statiometer, metallic tap measure (Cescorf®, Brasil); weighing machine (Swan, China). The “MEDSIZE_Man_2017” Excel® file was used to proceed with the data.

Air displacement plethysmography measurement: To determine the percentage of the body fat using the ADP technique, we used the Bod Pod® device (*Life Measurement Inc*. Corcord - USA). All measures were realized by the same evaluator, the same device, and the same software (1.69 version taking into account manufactory recommendations) [Dempster and Aitkens 1995]. The device was calibrated previously to the evaluations, entering a cylinder with a constant value (in liters) in the empty chamber. Then, subjects were weighed with the scale of the device, and pulmonary air was corrected with the thoracic gas by inhalation and exhalation with mechanical obstruction [Lazzer *et al.* 2008]. The percentage of body density was determined by the equation from Siri [1961]. The procedures performed were the following:
I. Coming to the evaluation site in a fasting state with 4 hours of anticipation.
II. Realizing height and weight measurements.
III. Putting swimsuit and swimming cap.
IV. Waiting for the calibration of the device.

Anthropometric equations to estimate body fat percentage (BF%): To determine the percentage of the BF, equations employed in our study were selected from the scientific literature [Bridge *et al.* 2014]. Table 2 presents the information relative to each of these equations: the complete formula as well as the specific population in which it had been developed.

Statistical analyes
Statistical analysis was performed using SPSS software (version 25). The alpha level was set to 0.05, and data results were shown as means ± standard deviation. The normality of the distribution was checked with the Shapiro-Wilk test, and the homogeneity of variance was tested by Levene’s statistics. Data having a non-normal distribution were logarithmically transformed and re-analyzed before their use in parametric tests. One-way analysis of variance ANOVA followed by Tukey’s test for multiple comparisons were realized to distinguish differences, with ADP as the gold standard. Regression analysis was used to evaluate the precision of the instruments, with the degree of variation between the measures. The Pearson test. was used to identify correlations between variables. Standard error with values between 2 and 3% was considered as good, whereas values greater than 4% were considered poor [Cauble, Dewi, Hull 2017]. For the concordance analysis between the different methods, we used the Intraclass Correlation Coefficient where the values obtained correspond to different grades of concordance: values >0.90 = very good concordance; between 0.71 - 0.90 = good concordance;

Table 2. Anthropometric equations to estimate BF%.

Authors	Age (years)	Equations	Population
Siri [1961]	–	BF% = (4.95/D) -4.5 x 100	Adults
Brozek et al. [1963]	–	BF% = (4.57/D) -4.142 x 100	Young and adults
Withers et al. [1987]	15 – 39	D = 1.0988 – (0.0004 x TR + SB + BI + SE + AB + FT + CH) *	Athletes
Katch & McArdle [1973]	18 – 27	BD = 1.09665 – 0.0103 (TR) – 0.0056 (SB) – 0.0054 (AB) #	Young and adults
Durnin & Womersley [1974]	16 – 72	BD = 1.1765 – 0.0744 x Log (TR + SE + SI+ BI) *	General population
Jackson & Pollock [1978]	18 – 61	D = 1.112 – 0.00043499 (CH+MR+TR+SE+AB+SI+FT) + 0.00000055 $(CH+MR+TR+SE+AB+SI+FT)^2$ - 0.00028826 (Age) *	Men
Faulkner [1968]	18 – 25	BF% = 5.783 + 0.153 (TR + SB + SI + AB)	Athletes
Carter [1982]	NR	BF% = 0.1051 x (AB + SE + TR+ CH+ MC)	Olympic athletes
Yuhasz [1974]	18 – 25	BF% = (TR+SB+SI+AB+FT+CA) x 0.095 + 3.64	Young athletes

Abbreviations: BF%: body fat percentage; BD: body density; D: density; TR: triceps; CA: calf; SB: subscapular; BI: biceps; SI: suprailiac; SE: supraspinal; AB: abdominal; FT: front thigh; CH: chest; AR: arm circumference relaxed; AC: abdominal circumference; FC: forearm circumference; MR: midaxillary region; MC: medial calf. *Siri [1961]; # Brozek *et al.* [1963].

between. 0.51 - 0.70 = moderate concordance; between 0.31 - 0.50 = poor; values 0.30 = bad or null. [Prieto, Lamarca, Casado 1998; Diaz-Garcia, Gonzalez-Zapata, Estrada-Restrepo 2012]. The percentage of error of each equation was calculated with the following formula:

$$\frac{\text{(Equation percent BF result - ADP percent BF result) x 100}}{\text{ADP percent BF result}}$$

The percentages obtained with each equation for body fat were compared with the results obtained with the ADP method [Teresa, Douglas, Kenedy 2012]. The comparison or limit of concordance was assessed by the Bland-Altman method, comparing the results of body fat obtained through the equations, with the results given by the ADP method [Bland, Almant 1986a; Bland Altman 2010b]. The significance level was assessed to <0.05.

Results

Comparative analysis between the percentage of fat measured by ADP and skinfolds using different equations

The analysis of variance, the Pearson correlation coefficient, and the regression analysis with their standard error of estimate (SEE), are reported in **Table 3.** Comparison between the percentages of body fat measured by ADP and those obtained with skinfolds measure and their equations was realized using a one-way ANOVA. This analysis did not show significant differences with ADP for any of these equations (p>0.05). Correlational analyses show that only percentages of body fat determined with the equations of Siri, Whiters, Durnin & Womersley, Carter, Yuhasz, Katch & McArdle and Faulkner, present a very high association (0.7-0.9; p<0.05) with those of ADP.

Table 3. Comparison between the percentage of body fat (% BF) estimated by plethysmography (ADP) and Anthropometric measurement.

Equations	BF%	p	r	R^2	SEE
Siri	12.7 ± 3.8	0.106	0.84*	0.71*	1.79
Withers et al	9.6 ± 3.8	0.944	0.78*	0.61*	1.82
Katch & McArdle	9.1 ± 3.4	0.990	0.74*	0.55*	1.77
Durnin & Womersley	12,6 ± 4.8	0.157	0.78*	0.62*	2.39
Faulkner	11,6 ± 2.5	0.247	0.72*	0.52*	1.28
Jackson & Pollock	13,3 ± 8.1	0.374	0.52	0.27	7.83
Carter	6.6 ± 1.8	>0.999	0.76*	0.59*	0.86
Yuhasz	7.9 ± 2.2	>0.999	0.76*	0.58*	1.05
Plethysmography	8.9 ± 5.4	–	–	–	–

Abbreviations: ADP: air displacement plethysmography; BF%: body fat percentage; *p<0.05 vs ADP; SEE: standard error of estimate; BF% data are presented as mean ± SD.

In addition, regression analysis found that the formulas that were most related to ADP were: Siri, Whiters, Durnin & Womersley and Katch & McArdle (R^2: 0.62-0.71), obtained the highest values concerning the relationship with ADP.

The equation of Durnin & Womersley showed values with a SEE (2.39) within the “good ranges” according to [Cauble, Dewi, Hull 2017].

Interpretation of values of the Intraclass Correlation Coefficient (ICC) was suggested by Prieto *et al.* [1998]. We found a higher correlation between ADP and the equation of Withers et al. (ICC: 0.913), classifying it as very good. The equations of Katch & McArdle, Durnin & Womersley, Siri, Yuhasz and Faulkner presented good correlation with ADP (ICC: 0.891, 0.821,0.779, 0.777 y 0.725, respectively), whereas the equation of Carter presented a moderate correlation (ICC: 0.636), and that of Jackson & Pollock (ICC: 0.466) a poor correlation (Table 4).

Table 4. Agreement ICC between ADP and anthropometric measurements.

Equations	ICC	IC 95 %	p
Siri	0.779	-0.20-0.95	<0.001
Withers et al	0.913	0.70-0.97	<0.001
Katch & McArdle	0.891	0.61-0.96	0.001
Durnin & Womersley	0.821	-1.72-0.96	<0.001
Faulkner	0.725	0.01-0.92	0.006
Jackson & Pollock	0.466	-0.45-0.83	0.120
Carter	0.636	-0.08-0.89	0.034
Yuhasz	0.777	0.25-0.93	0.010

Abbreviations: ICC: Intraclass correlation coefficient; IC: Confidence interval. *p<0.05: significance for Intraclass correlation coefficient with ADP

Bland-Altman Agreement and Intraclass correlation coefficient.

The results of the statistical analysis showed that the mean difference (MD) (Table 5) was the closest of zero between BF% and ADP were observed for the equations of Katch & McArdle (+0.18; 95% CI, -5.5 to 5.9), Withers et al. (+0.74; 95% CI, -4.4 to 5.9) and Yuhazs (-0.93; 95% CI, -7.8 to 5.9), whereas that of Carter's equation reported a higher value (-2.22; 95% CI, -9.8 to 5.4).

On the other hand, equations with the MD farthest from the black midline were the following, in descending order: Jackson & Pollock (4.43 ± 7.8; p>0.05), Siri (3.56 ± 2.5; p<0.05), Durnin & Womersley (3.52 ± 2.5; p<0.05) and Faulkner (2.74 ± 3.3; p<0.05). The Jackson & Pollock equation was the only one to get over 2±SD of the mean.

To determine the concordance between the results of BF% obtained with ADP and skinfold measures, we used the Bland-Altman Plot. The results are presented in Figure 1, only for the equations in which differences of means were close to zero. Statistical information of equations used with the Bland-Altman plot is presented in Table 5.

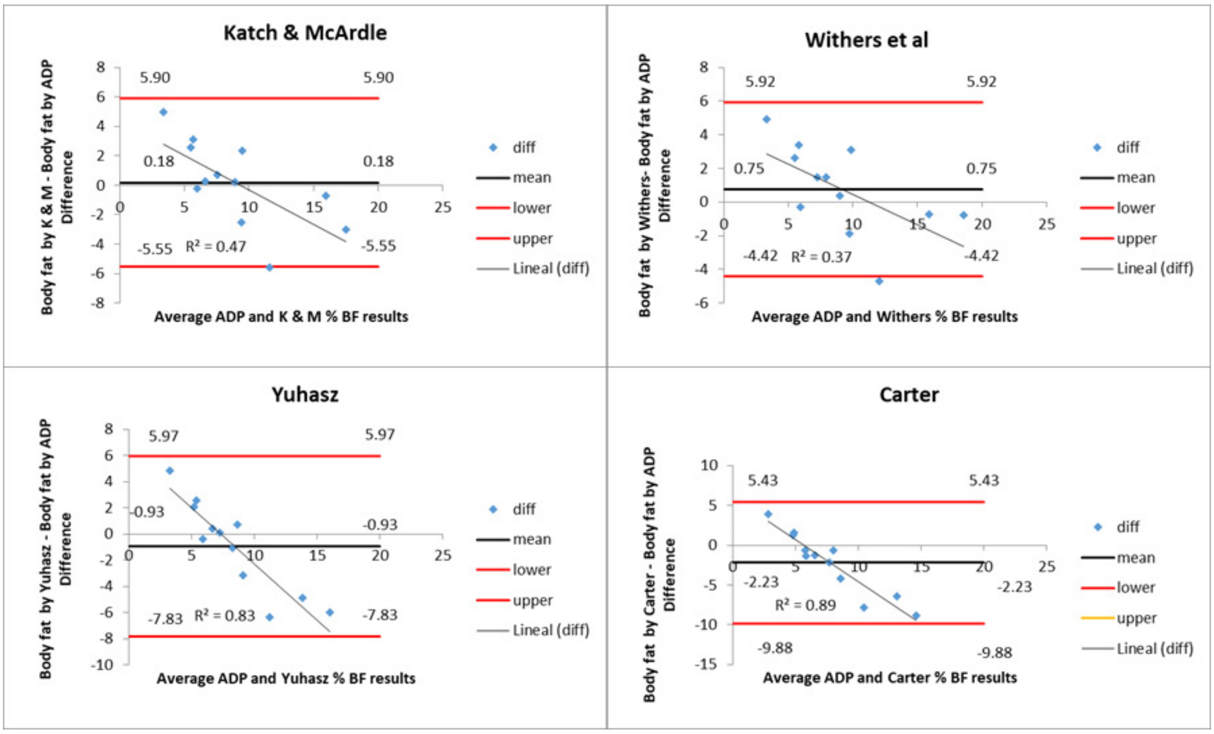

Figure 1. Comparison of predicted BF% between equations of Katch & McArdle, Withers et al, Yuhasz, Carter and ADP by Bland–Altman plots. The central lines represent the average of the results of the methods. The upper and lower lines represent the 95% limits of agreement.

All equations presented a variation in the percentage of error (Vpe) with values between -10% and 50% (Table 5). Some equations highly overestimated it:

Jackson & Pollock (50%) Siri (43%) and Durnin & Womersley (42%), whereas other presented the smallest values: Katch & McArdle (2%) and Withers (8%).

Regarding the mean of the errors (M% e) of all equations, we observed the smallest value for the Siri equation (0.74%), while that of Jackson and Pollock presented the highest M% e (2,25%).

Table 5. Results from Bland-Altman and variation in percent error (Vpe).

Equations	MD±SD	p	Loa	M%e	Vpe (%)
Siri	3.56± 2.5	<0.001	-1.4, 8.5	0.74	43
Withers et al	0.74± 2.6	0.346	-4.4, 5.9	0.76	8
Katch & McArdle	0.18 ± 2.9	0.838	-5.5, 5.9	0.84	2
Durnin & Womersley	3.52 ± 2.5	<0.001	-1.4, 8.5	0.76	42
Faulkner	2.74 ± 3.3	0.017	-3.8, 9.3	0.97	31
Jackson & Pollock	4.43 ± 7.8	0.075	-10.8, 19.7	2.25	50
Carter	-2.22 ± 3.9	0.074	-9.8, 5.4	1.12	-25
Yuhasz	-0.93 ± 3.5	0.379	-7.8, 5.9	1.01	-10

Abbreviations: MD: mean difference; SD: standard deviation; Loa: limits of agreement; M%e: mean % error; Vpe: variation in percent error.

Discussion

ADP is a common reference method in the evaluation of body composition, however, its cost is too high to be used frequently in the evaluation of human subjects [Zanini *et al.* 2015]. To overcome this issue, the use of equations based on skinfold measures presents multiple benefits, although to date there are no studies focusing on the determination of the most reliable equation to evaluate body fat percentage (BF%) in elite taekwondo athletes [Bridge *et al.* 2014].

In this study, we compared the ADP method with various skinfold measure equations to determine BF% in elite taekwondo athletes. We used various statistical analyses to determine which equation could be the most suitable to assess BF% with close values to those obtained with ADP, our reference method.

The first inferential analysis used to compare the results of the selected equations and ADP did not exhibit differences between means, although it did show high correlations (Table 3).

However, and as was previously mentioned, various authors argue that the use of Pearson's correlation is not appropriate when we want to establish the agreement between different methods [Altman, Bland 1983; Hebert, Miller 1991; Bellach 1993]. Similarly, regression analysis is neither recommended as a comparison test and is rather used to determine the level of precision [Bland, Almant 1986a; Bland, Altman 2010b; Cauble, Dewi, Hull 2017]. Repeatability, which can be measured by Intraclass Correlation Coefficient (ICC), is considered to be of great importance in the comparison of evaluation techniques. Its objective is to verify if a method can be compared regardless of units of measure. Previous studies used ICC as an interesting tool to compare different evaluation methods [Braulio *et al.* 2010; Verney *et al.* 2015; Montgomery, Marttinen, Galpin 2017; Ferri-Morales *et al.* 2018; Delisle-Houde *et al.* 2019]. Among the limitations of ICC, we can note that data should present a normal distribution, equality of variances and independence between errors of each observer [Cortes-Reyes, Rubio-Romero, Gaitan-Duarte 2010]. Values obtained in ICC superior to 0.71 are considered as optimal for repeatability [Prieto, Lamarca, Casado 1998; Diaz-Garcia, Gonzalez-Zapata, Estrada-Restrepo 2012]. In our study, the Withers et al. and the Katch & McArdle were the two equations with higher ICC (0.913 and 0.891, respectively), although the confidence interval (IC) was moderate, probably due to the sample size [Prieto, Lamarca, Casado 1998].

Unlike ICC, the Bland-Altman method is the main tool to evaluate the degree of agreement between two measurement tools. In our study, analysis using this method showed a high degree of agreement between results of the Katch & McArdle equation and those obtained by the ADP method. The use of the Bland-Altman statistical technique increased in the last years due to its specificity, reliability and facility in data interpretation through an easy and visual way [Dewitte *et al.* 2002].

Studies investigating BF% and establishing a concordance between results from equations and from a reference method have previously been conducted in various populations, such as wrestlers [Carey 2000] elite sport climbers [Romero *et al.* 2009], paralympic athletes [Lemos *et al.* 2016], male collegiate hockey players [Delisle-Houde *et al.* 2019] and Taekwondo athletes [Moreira *et al.* 2012].

Our study shows that the Katch & McArdle equation appears to be the most suitable to determine BF% in elite taekwondo athletes, as indicated by the results of the ICC analysis as well as the Bland-Altman method. Besides these findings, we highlighted that one of the characteristics of the Katch & McArdle equation is that it is easy to use, as it requires the measure of only 3 skinfolds. Similar results were observed by Carey [2000] in collegiate wrestlers. Carey's study reported that the equation reaching the values closest to those of reference, acquired with hydrostatic weighing as a method of comparison, was also the equation of Katch & McArdle, and the furthest one was that of Jackson & Pollock. Besides, the study of Moreira *et al.* [2012], also conducted in taekwondo athletes, compared BF% obtained with the skinfolds measure with those obtained with the DXA "gold standard". Nevertheless, the results of Moreira's study should not be compared with ours, as the equations and method used were different, and the population too (the cohort of athletes was 12 years old). Scientific investigations focused on the determination of concordance degree between equations and laboratory techniques, regarding BF% in taekwondo athletes are scarce. That is a major limitation of the contrast results observed in our present study. However, we think that our highlights are of major importance in the context of high-level performance, as we give interesting tools to trainers and researchers who, most of the time, do not have access to modern and expensive techniques.

When interpreting these findings, some limitations should be kept in mind. First, in our study, the ADP method was used as the reference method but nowadays, we know that other techniques such as DXA, RX and MRI are considered to be more precise [Norgan 2005]. However, the elevated cost and accessibility of these devices make them difficult to use. In addition, when using DXA o RX, subjects are exposed to a low dose of radiation which is absent with the ADP method – making it another argument in favor of the use of that method.

A second limitation in our study is the low number of participants, which could eventually affect the results that we found. However, our subjects are of valuable as avowed elite athletes. Likewise, we proposed the first study evaluating the agreement between two methods of BF% determination, in elite taekwondo athletes.

Conclusions

Based on our results, the equation of Katch & McArdle based on skinfold measures presents the highest degree of concordance with ADP method in the determination of BF%. Thus, our study supports the utility of skinfold-based equations as an appropriate technique to estimate the BF% in elite male taekwondo athletes, through the use of that equation. Further investigations are required to validate the determination of BF% by using this equation in various populations, for example, not only elite male athletes but also female athletes and non-elite athletes of different ages and competition categories.

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Conflicts of interest and other problems

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. All authors read and approved the final manuscript.

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Porównanie pletyzmografii i wskaźnika zawartości tkanki tłuszczowej u elitarnych zawodników taekwondo

Słowa kluczowe: sztuki walki, ocena antropometryczna, skład ciała, grubość fałdu skórnego, pneumatyczna pletyzmografia wyporowa

Streszczenie

Wprowadzenie. W taekwondo, skład ciała i procentowa zawartość tłuszczu w organizmie (BF%) są czynnikami decydującymi o wyniku walki u elitarnych sportowców. W ostatnich latach pletyzmografia wyporu powietrza (ADP) stała się metodą referencyjną do oceny wartości procentowej zawartość tłuszczu w organizmie, podczas gdy równania oparte na fałdzie skórnym mogą być stosowane w przypadkach, gdy nie ma dostępu do odpowiedniego sprzętu.

Problem i cel: Określenie stopnia zgodności pomiędzy wartością BF% ocenianą metodą ADP a różnymi metodami pomiaru fałdu skórnego u zawodników taekwondo.

Metody. Dwunastu brazylijskich elitarnych sportowców (19,5± 3,8 lat) zostało ocenionych przy użyciu protokołu International Society for the Advancement of Kinanthropometry (ISAK). Procentowa zawartość tłuszczu w organizmie oceniano przy użyciu 9 równań opartych na pomiarze fałdu skórnego, których wyniki porównano z wynikami metody ADP.

Wyniki. Średnia wartość BF% mierzonego metodą referencyjną wynosiła 8,9 ± 5,4. Zgodność pomiędzy metodami ADP i skinfold badano metodą Blanda-Altmana. Najwęższe granice zgodności w stosunku do metody referencyjnej wystąpiły dla równania Katcha i McArdle'a
(-5,5, 5,9) i obejmowały 95% (11/12) ocenianych różnic. Średnia różnica pomiarów pomiędzy ADP a metodami antropometrycznymi wyniosła (0,18±2,9).

Wnioski. Uzyskane wyniki sugerują, że równanie Katcha i McArdle'a, wykorzystujące gęstość ciała z równania Brożka i inn. [1963], można uznać za najbardziej odpowiednie do określania procentowej zawartości tłuszczu w organizmie, gdyż jego wyniki są najbardziej zbliżone do wyników uzyskanych metodą ADP. Równanie to charakteryzuje się dobrą powtarzalnością i zgodnością, małym błędem procentowym oraz łatwością wykorzystania w ocenie zawartości tłuszczu w organizmie zawodników taekwondo.