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KINESIOLOGY

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Relationship between frequency speed of kick test performance, optimal load, and anthropometric variables in black-belt taekwondo athletes

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Key words: measure, specific evaluation, combat sports, performance

Abstract

Aim. The purpose of this study was to verify the relationship between frequency speed of kick test (FSKT) performance, optimal load, and anthropometric characteristics in taekwondo athletes.

Material and Methods. Sixteen black-belt *taekwondo* athletes volunteered to participate in the study. FSKT performance with durations of 10s and 90s, optimal load in jump squat and bench throw, and anthropometric characteristics were measured, including somatotype.

Results. Significant correlations were found between height and $FSKT_{10s}$ (r_s = -0.53 [large]; p = 0.017), height and $FSKT_4$ (r_s = -0.514 [large]; p = 0.021), and body fat (kg) and $FSKT_4$ (r_s = -0.606 [large]; p = 0.006). The ANOVA ($F_{1.68, 25.20}$ = 23.28; p<0.001; η^2 = 0.608 [large]; post hoc observed power: 1.00) results indicated that the number of kicks during $FSKT_1$ (Mean±SD: 21±2) was superior to $FSKT_2$ (20±2), $FSKT_3$ (19±2), $FSKT_4$ (18±2), and $FSKT_5$ (18±2) (p <0.01). The number of kicks during $FSKT_2$ was superior to $FSKT_3$, $FSKT_4$, and $FSKT_5$ (p <0.05). The number of kicks during $FSKT_3$ was superior to $FSKT_4$ (p <0.05).

Conclusions. The FSKT is a field test that correlates with physical characteristics important to the performance of taekwondo athletes and which can be conducted in training centers. Additionally, FSKT is a new field taekwondo test that presents peak of kicks, total kicks and kick decrement index. Coaches and strength and conditioning professionals will benefit from using this tool to monitor taekwondo athletes.

Introduction

Taekwondo is a combat sport, with intermittent characteristics, in which athletes perform complex high-intensity movements, followed by periods of activity at low-intensity or pauses [Bridge *et al.* 2014; Santos, Franchini, Lima-Silva 2011]. Matches are structured across six minutes, divided into three two-minute rounds with a one-minute break between them [World Taekwondo, 2016]. The purpose of a taekwondo match is to make the most points without suffering counterattack or knockout of the opponent. Considering these purposes, it is important for taekwondo athletes to develop anaerobic conditioning during the competition season [Ball, Nolan, Wheeler 2010]. The anaerobic conditioning is a necessary characteristic for successful application of kicks during all *taekwondo* matches.

The most commonly used test to measure anaerobic power in taekwondo athletes is the Wingate test [Bridge *et al.* 2014], but unfortunately, specific field tests to assess anaerobic physical fitness are less widely known [Santos *et al.*, 2016; Santos, Valenzuela, Franchini, 2015; Sant'Ana *et al.* 2014; Sant'Ana, Silva, Guglielmo 2009]. The frequency speed of kick test (FSKT) has been used to measure performance in recent investigations [Santos *et al.* 2016; Santos, Valenzuela, Franchini 2015]. The FSKT is performed in two forms, the first composed of one 10s set and the second of five 10s sets with a 10s

rest interval between sets. Variables generated are: kick number in each set, total kick number, and kick decrement index (KDI) [Santos *et al.* 2016; Santos, Valenzuela, Franchini 2015]. These variables can be used to define the performance, however, no study has correlated FSKT with anthropometrical characteristics such as height, weight, and body fat for example. Taekwondo athletes desire maintenance or reduction in body mass, muscle mass and low body fat because these characteristics maybe are associated with success [Bridge *et al.* 2014]. However, until the present moment, it is not known whether the same characteristics are necessary for good performance during the FSKT.

Different behavior is expected in field tests using specific gestures which can be quickly and easily applied. Currently, there are few investigations using specific taekwondo gestures [Santos *et al.* 2016; Santos, Valenzuela, Franchini 2015; Sant'Ana *et al.* 2014; Sant'Ana, Silva, Guglielmo 2009]. For this reason, the purpose of the present study was to investigate the relationship between FSKT performance, optimal load, and anthropometric characteristics in taekwondo athletes. There was expected an association between FSKT performance and anthropometric variables, specially body fat and lean body mass, and between FSKT and neuromuscular performance.

Material and Methods

Participants

Sixteen male black-belt taekwondo athletes volunteered to participate (age: 23±5 years; height: 180±7 cm; weight: 73±13 kg; experience time: 11±5 years) and provided written consent after being informed about the procedures and risks associated. The athletes were competing at a regional or more prominent level (international: 3; national: 5; state: 6; regional: 2) and trained in taekwondo 5-times per week, with a 2-h duration per session. Prior to testing, the athletes were informed of the procedures, including the possible risks involved, and signed an informed consent form. They were free from any injury or neuromuscular disorder. The research was approved by the Institutional Ethics Committee.

Study Design

This is a cross-sectional association study among physical, muscular power and FSKT of male black-belt taekwondo athletes. All athletes involved in this study had experience with testing procedures, including FSKT. The tests were executed in center training of each athlete, during competitive period. The assessment was performed at the same period (starting 9 AM) following order physical measurement, muscular power, $FSKT_{10s}$ and $FSKT_{mult}$. Rest interval of 20 minutes among tests were applied. Before testing session, a general and specific warm-up routine were realized, composed by running, stretching and low intensity kicks and punches, totalizing approximately 15-minutes.

Procedures

Anthropometric Variables

Body mass and Height. Body mass was measured using a scale accurate to 0.1 kg and height using a stadiometer accurate to 0.1 cm. Body mass and height were used to calculate the body mass index (BMI), using the formula: kg/m^2.

Perimeters. Perimeters were measured and used to calculate the somatotype as described previously by the International Society for the Advancement of Kineanthropometry standardization (ISAK) [Norton, Olds 1996].

Skinfolds. The skinfolds measured were chest, mid-axillary, triceps, subscapular, abdominal, and thigh. The skinfolds were used to calculate somatotype. All procedures adopted followed ISAK standardization [Norton, Olds 1996].

Body Density. Body density (BD) was estimated using Jackson and Pollock's [Jackson, Pollock 1978] formula, as follows.

$$BD = 1.112 - .00043499\ (\Sigma 7EDC) + .00000055\ (\Sigma 7EDC)^2 - .00028826\ (age)$$

$\Sigma 7EDC$ = is the sum of seven skinfolds (chest, midaxillary, triceps, subscapular, abdominal, suprailiac, and thigh).

Body Fat. Siri's [Siri, 1961] equation was used to estimate body fat (BF), as follows.

$$BF\% = [(4.95/BD)] - 4.50] \times 100$$

BF% is the percentage of BF.

Somatotype. Determination of somatotype was calculated following Health and Carter [Health, Carter 1967] protocols. Weight, height, diameters (humeral and femoral), girth (arm contracted and medial calf), and skinfold thickness (triceps, subscapular, suprailiac, and medial leg) were included to calculate somatotype components.

Frequency Speed of Kick Test. The FSKT had duration of 10s and was described in a previous study [Santos, Valenzuela, Franchini 2015]. During its execution each athlete was placed in front of the stand bag equipped with a simple trunk taekwondo protector. After a command, the athlete performed the maximal number of

kicks possible, alternating right and left legs. The turning kick, known as *Bandal Tchagui*, was used during test.

Performance Variables

Frequency Speed of Kick Test Mult. The same procedures adopted in the $FSKT_{10s}$, were used during the FSKTmult. In this study, each athlete performed five FSKTs with a 10s rest interval between repetitions. Performance was determined by the total number of kicks in each set, the total number of kicks in five sets, and the kick fatigue index. FSKT multiple sets presented mean intraclass correlation coefficient (ICC) = .85 between test and retest. The mean coefficient of variation between test and retest was 3.9%.

Kick Decrement Index. Kick decrement indicates performance decrease during the test [Santos, et al., 2016]. To calculate the kick decrement the number of blows applied during the multiple FSKT was considered. The equation takes into account the results of all FSKT sets (Equation) [Girard, Mendez-Villanueva, Bishop 2011].

$$\text{KICK DECREMENT INDEX (\%)} = = \left[1 - \frac{(FSKT1+FSKT2+FSKT3+FSKT4+FSKT5)}{\text{Best FSKT SET X Number of Sets}}\right] \text{x } 100$$

Squat Jump and Countermovement Jump Heights. The taekwondo athletes were allowed five attempts, interspersed by ~15 second intervals between each jump. All jumps were performed with hands on the hips. During the squat jump, a static position with 90 degree knee-flexion was maintained for approximately 2 seconds before a new jump attempt, without preparatory movement. During the countermovement jump, athletes were instructed to perform a downward movement followed by a complete extension of the lower limb joints. The jumps were performed on a mat platform (smart jump; fusion sport, Coopers Plains, Australia) with the recorded flight time (t) being used to estimate the height (h) of the rise of the body's center of gravity during a vertical jump. The best attempt was retained for data analysis.

Loaded Bench throw (BT) and Jump Squat (JS). A linear transducer (T-Force, Dynamic Measurement System; Ergotech Consulting S. L., Murcia, Spain) was attached to the smith machine bar (adapted by Hammer Strength, Rosemont, USA) to determine MPP. Bar position data were sampled at a frequency of 1000 Hz and recorded in a computer. During the BT, the taekwondo athletes were instructed to lower the bar until it touched the chest and, after a command, throw it as high and fast as possible. The JS started from a static squat position (90 degree knee flexion), and after a command, the participants jumped as high as possible, without their shoulder losing contact with the bar. The athletes were instructed to execute three repetitions for each load, starting at 30% of their body mass in the BT and 40% of their body mass in the JS. A load of 5% and 10% of body mass was gradually added in each set for BT and JS, respectively, until a decrease in mean propulsive power (MPP) (W) performance was observed. MPP load (kg) and MPP relative (W/kg) were obtained based on MPP. Mean propulsive power was measured considering only the concentric phase during which the acceleration is greater than acceleration due to gravity (i.e., $a \geq -9.81$ $m.s^{-2}$) [Sanchez-Medina, Perez, Gonzalez-Badillo 2010].

Statistical analysis

Data are presented as M, SD, and 95% confidence interval (95% CI). The Shapiro-Wilk test was used to assess data normality. Correlations were carried out using Spearman's correlation coefficients, calculated to examine the relationships between dependent (i.e., FSKT outcomes) and independent variables (i.e., anthropometric data and performance tests). The correlations were classified as 0.0 - 0.1 (trivial), >0.1 - 0.3 (small), >0.3 - 0.5 (moderate), >0.5 - 0.7 (large), >0.7 - 0.9 (very large), and >0.9 – 1.0 (nearly perfect) [Hopkins 2002], and only moderate and large correlations between the FSKT and other variables were presented. ANOVA one-way with repeated measures was used to check the differences between FSKT series, followed by the Bonferroni post-hoc test and observed power, which was the mainly test used. The Mauchly's test indicated that the sphericity assumption was violated (c^2 (9) = 33.5, $p < 0.05$), thus the degrees of freedom were corrected using the Greenhouse and Geisser estimate of sphericity (ε = 12:42). ANOVA was classified using the partial eta squared (η^2) according to the following scale [Cohen 1988]: small = 0.01; medium = 0.06; large = 0.14. The level of significance was set at 5%.

Results

Table 1 presents the anthropometric variables of the taekwondo athletes.

Table 1. Anthropometric characteristics of taekwondo athletes (n=16).

Variable	Mean (SD)	95% CI
Body mass (kg)	74 (12)	67 – 80
Body height (m)	1.80 (0.7)	1.76 – 1.84
BMI (kg/m²)	22.6 (2.6)	21.3 – 24.0
Body fat (%)	9.4 (4.4)	6.9 – 11.6
Body fat (kg)	7.0 (3.9)	4.9 – 9.1
LBM (kg)	66.5 (9.8)	61.2 – 71.8
Somatotype		
Endomorph	3.7 (1.5)	2.8 – 4.5
Mesomorph	4.9 (1.2)	4.3 – 5.5
Ectomorph	3.0 (1.1)	2.4 – 3.6

BMI = Body mass index; LBM = lean body mass. SD: standard

deviation, 95% CI: 95% confidence interval.

Table 2 presents variables related to physical performance.

Table 2. Physical performance of taekwondo athletes (n=16).

Variable	Mean (SD)	95% CI
SJ (cm)	35.7 (5.8)	32.7 – 38.8
CMJ (cm)	36.4 (5.9)	33.3 – 39.6
Bench Throw		
MPP (W)	418.0 (103.5)	362.8 – 473.1
MPP Load (kg)	26.5 (5.6)	23.5 – 29.5
MPP Relative (W/kg)	5.5 (1.0)	5.0 – 6.1
Jump Squat		
MPP (W)	650.7 (192.0)	548.4 – 753.0
MPP load (kg)	53.1 (14.5)	45.4 – 60.9
MPP Relative (W/kg)	8.6 (2.0)	7.5 – 9.7
FSKT		
$FSKT_{10s}$	20 (3)	19 – 22
$FSKT_{mult}$		
$FSKT_1$*	21 (2)	19 – 22
$FSKT_2$**	20 (2)	18 – 21
$FSKT_3$***	19 (2)	18 – 20
$FSKT_4$	18 (2)	17 – 19
$FSKT_5$	18 (2)	17 – 19
$FSKT_{total}$	95 (9)	90 – 100
Kick Decrement Index (%)	7.5 (3.6)	5.5 – 9.4

MPP: Mean propulsive power; FSKT: Frequency Speed of Kick Test; SD: standard deviation, 95% CI: 95% confidence interval.* $FSKT_1$ was different from conditions $FSKT_2$, $FSKT_3$, $FSKT_4$ and $FSKT_5$ ($p < 0.01$). **$FSKT_2$ was different from conditions

Significant correlations were only found between: height and $FSKT_{10s}$ (r_s = -0.53 [large]; p = 0.017), height and $FSKT_4$ (r_s = -0.514 [large]; p = 0.021), and BF (kg) and $FSKT_4$ (r_s = -0.606 [large]; p = 0.006).

The ANOVA results indicated that the FSKT series were significantly different (F (1.68, 25.20) = 23.28; $p<0.001$; $\eta^2 = 0.608$ [large]; post hoc observed power: 1.00) (Table 2). The number of kicks during $FSKT_1$ was superior to $FSKT_2$, $FSKT_3$, $FSKT_4$, and $FSKT_5$ ($p <0.01$). The number of kicks during $FSKT_2$ was superior to $FSKT_3$, $FSKT_4$, and $FSKT_5$ ($p <0.05$). The number of kicks during $FSKT_3$ was superior to $FSKT_4$ ($p <0.05$).

Discussion

The purpose this study was to verify the relationship between FSKT, optimal load, and anthropometric characteristics in taekwondo athletes. The main contribution of this study was the description of new tests being used in combat sports athletes, specifically taekwondo, as in the case of tests with FSKT and optimal load. In addition, few correlations were observed between FSKT and anthropometric variables. These findings could help trainers and coaches to better understand the interaction between anthropometric variables and specific taekwondo performance, as well as assist them in understanding the results obtained.

The taekwondo athletes who participated in this study presented low body fat percentage and body mass, consistent with those reported in a recent literature review [Bridge *et al*. 2014]. The literature describes that male taekwondo athletes have fat percentage between 7% and 20% [Bridge, *et al*. 2014; Taaffe, Pieter, 1990] and international level athletes between 7% and14% [Chiodo *et al*. 2011; Ghorbanzadeh *et al*. 2011; Pilz-Burstein *et al*. 2010; Úbeda *et al*. 2010; Lin *et al*. 2006; Olds, 2000; Pieter, Taaffe 1990; Taaffe, Pieter 1990]. In this study, it was reported fat percentages within the range described in literature. This may be mainly because the majority of athletes in the sample participated in high weekly training volumes. Although it is still not possible to make recommendations as to the ideal body fat percentage for a taekwondo athlete, it is clear that a low percentage of body fat is desirable for good performance in competitions [Bridge *et al*. 2014].

The taekwondo athletes of this study were classified as endo-mesomorphic (Table 1), characterized by having a high proportion of mesomorphic component, indicating predominance of skeletal muscle mass [Bridge *et al*. 2014]. The literature tends to describe the second component presented by taekwondo athletes as ectomorphic, indicating higher linearity, and finally, the endomorph component, accounting for the low percentage of fat [Leon, Viramontes, Veitia 2009; Fritzsche, Raschkam 2008; Pieter 2008; Pieter 2001; Olds 2000; Pieter, Taaffe 1990; Taaffe, Pieter 1990], being classified as ecto-mesomorphic. This characteristic, higher linearity means the athletes reach the opponent during a match, without conceding counterattacks that result in scores. However, in some instances, athletes have the reverse order of the somatotype components, the second component being classified as endomorphic, followed by ectomorphic (Endomorph, mesomorph, ectomorph: 4.2, 4.7, 3.8) being classified as endo-mesomorph [Chan, Pieter, Moloney 2003]. Similar results were found with the athletes in the present study (Table 1). Additionally, the taekwondo athletes who composed the sample of this study presented high muscle mass and low body fat percentages, as shown in Table 1. These characteristics may be necessary to increase performance [Bridge *et al*. 2014].

The FSKT has been used in recent studies [Santos *et al*. 2016; Santos, Valenzuela, Franchini, 2015] and it is a test that utilizes a specific gesture, the *bandal tchagui*, which is the most commonly used gesture during taekwondo competitions. Additionally, FSKT generates information that can perhaps be associated with performance during the match, such as the peak, total, and decrease in kicks applied. The results generated in the present study were similar to previous studies, which

showed a reduction in the number of kicks over $FSKT_{mult}$ [Santos, Valenzuela, Franchini 2015]. The decrease generated during this study was lower than that observed in the previous study. This feature may be associated with the physical condition and technical quality of the athletes comprising the respective samples. Although the number of kicks applied in the first series was ~20 in both studies, in the present study the athletes applied more kicks in the following series in comparison with previous studies [Santos, Valenzuela, Franchini 2015]. We suggest that this may have occurred because of the technical quality and/or better physical condition of the athletes in the present study. Another possibility is that in the Santos study the athletes may have applied kicks with a greater force component, which could result in fewer kicks and punches. Although the test is explained according to the description, athletes can take different positions during the execution.

Some correlations between anthropometric characteristics and performance during FSKT were observed in this study. A negative correlation was observed between height and $FSKT_{10s}$ (r_s = -0.53 [large]; p = 0.017) and height and $FSKT_4$ (r_s = -.514 [large]; p = 0.021), indicating that taller taekwondo athletes can perform a lower number of repetitions in the FSKT, compared to shorter athletes. This may be due to the fact that taller athletes need more time than shorter athletes to go through the space equivalent to the height of the trunk itself. The target was set for each performer, according to their height. Body fat mass was negatively correlated with $FSKT_4$ (r_s = -0.606 [large]; p = 0.006). This result reinforces the statement made previously that it is desirable for athletes to have low percentages of fat to optimize their performance.

Finally, the main limitation of the present study was the lack of sequential measures during season to understand the behavior of physical and muscle characteristic of black-belt athletes. However, this is one of the first studies to investigate possible relationships between different tests routinely used by high performance taekwondo athletes.

Conclusion

In conclusion, FSKT is a specific test for taekwondo athletes that correlates with any anthropometric characteristics as height and body fat and can be used during the season to measure performance. These findings suggest that coaches and strength and conditioning professionals should improve the capacity of athletes to develop fast movements to better perform taekwondo-specific kick. Additionally, it is desired to keep a low value of body fat to maintain or improve performance, as higher amount of body fat is associated with lower performance in fast sequential kicks. Coaches and strength and conditioning professionals should consider these tools to measure and prescribe exercises. Finally, any correlations presented between test performance and anthropometry could possibly influence performance.

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Zależność między częstotliwością prędkości kopnięcia w czasie testu wydajnościowego, optymalnym obciążeniem i zmiennymi antropometrycznymi zawodników posiadających czarny pas w *taekwondo*

Słowa kluczowe: pomiary, ocena szczegółowa, sporty walki, wydajność

Abstrakt

Cel. Celem niniejszego badania było sprawdzenie zależności między częstotliwością prędkości kopnięcia (*ang.* skrót FSKT), optymalnym obciążeniem i cechami antropometrycznymi zawodników *taekwondo*.

Materiał i metody. Szesnastu sportowców, posiadających czarny pas w *taekwondo*, zgłosiło się na ochotnika do udziału w badaniu. Dokonano pomiaru osiągniętych wyników FSKT trwających 10s i 90s, przy optymalnym obciążeniu w trakcie skoku z przysiadem i podrzutu sztangi z pozycji leżacej z ławki oraz cechami antropometrycznymi, w tym somatotypem.

Wyniki. Podczas badania stwierdzono istotne korelacje między wzrostem a $FSKT_{10s}$ (rs = -0,53 [duże]; p = 0,017), wzrostem a $FSKT_4$ (rs = -0,514 [duże]; p = 0,021) oraz tkanką tłuszczową (kg) i $FSKT_4$ (rs = -0,606 [duże], p = 0,006). Test ANOVA ($F_{1.68, 25.20}$ = 23,28; p<0.001; η^2 = 0,608 [duże], siłą zaobserwowana po teście: 1,00) wykazał, że liczba kopnięć podczas $FSKT_1$ (Średnia ± SD: 21 ± 2) była większa od $FSKT_2$ (20 ± 2), $FSKT_3$ (19 ± 2), $FSKT_4$ (18±2), and $FSKT_5$ (18±2) (p <0.01). Liczba kopnięć podczas $FSKT_2$ była większa od $FSKT_3$, $FSKT_4$, and $FSKT_5$ (p <0.05). Liczba kopnięć podczas $FSKT_3$ była większa od $FSKT_4$ (p <0,05).

Wnioski. FSKT to test terenowy, który koreluje z cechami fizycznymi ważnymi dla wydajności sportowców taekwondo i który można przeprowadzić w ośrodkach szkoleniowych. Dodatkowo, FSKT jest nowym testem terenowym w taekwondo przedstawiającym maksymalną liczbę kopnięć, całkowitą ilość kopnięć i indeks redukcji kopnięć. Trenerzy oraz specjaliści od wzmacniania siły i kondycji mogą skorzystać z tego narzędzia do monitorowania sportowców *taekwondo*.