Anthropometric characteristics and physical performance of taekwondo athletes

Características antropométricas e desempenho físico de lutadores de taekwondo

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Abstract – The purpose of this investigation was to measure anthropometric and physical performance variables of TKD athletes from the city of Pelotas - RS. Forty-five athletes aged 16.4 ± 5.2 years and time of practice of 3.25 ± 3.6 years were evaluated. Athletes performed anthropometric evaluation and physical, general and specific performance tests. In the sum of seven skin folds, men presented lower values (106.1 ± 49.5 mm versus 143.4 ± 43.2 mm, p <0.002). Male seniors presented better performance in the vertical jump compared to beginners (42.3 ± 8.5cm versus 24.8 ± 10.1cm, p <0.03) and to women (22.1 ± 4.3cm, p <0.03). Graduated individuals perform higher number of arm pushups than beginners and women and more repetitions in the abdominal test. Male junior and senior athletes had higher isometric handgrip strength than females (48.3 ± 3.9 kgf and 38.1 ± 12.6 kgf versus 29 ± 5.6 kgf, p <0.001). Men covered longer distance in the yo-yo test than women (606.6 ± 233.8m versus 200 ± 113.1m, p <0.001). In the Wingate test, men produced greater peak and average relative power. No differences in flexibility were observed. In the single kick test, seniors kicked faster than less experienced athletes (200.6 ± 12.3m / s versus 258 ± 5.6m / s, p <0.001) and performed greater number of kicks in the 21s, 6 ± 2.1 reps versus 15.5 ± 0.7 reps, p <0.001). It was concluded that there are differences between male and female TKD athletes regarding anthropometric and motor characteristics, and that more experienced athletes exhibit greater general and specific physical fitness.

Key words: Body Composition; Martial Arts; Physical education and training.

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Resumo – *O objetivo desta investigação foi mensurar variáveis antropométricas e de desempenho físico de atletas de TKD da cidade de Pelotas – RS. Foram avaliados 45 atletas com idades 16,4±5,2 anos e tempo de prática de 3,25± 3,6 anos. Os atletas realizaram avaliação antropométrica, testes de desempenho físico, gerais e específicos. No somatório de sete dobras cutâneas, homens apresentam menores valores (106,1±49,5mm versus 143,4±43,2mm; p<0,002). Homens mais graduados apresentaram melhor desempenho no salto vertical que homens iniciantes (42,3±8,5cm versus 24,8±10,1cm; p<0,03) e que mulheres (22,1±4,3cm; p<0,03). Indivíduos graduados realizam maior número de flexões de cotovelo que iniciantes e mulheres e mais repetições no teste de abdominais. Atletas da categoria sênior e júnior masculino exibiram mais força isométrica de preensão manual que as mulheres (48,3±3,9kgf e 38,1±12,6kgf versus 29±5,6kgf; p<0,001). Homens percorreram maior distância no yo–yo test que mulheres (606,6±233,8m versus 200±113,1m; p<0,001). No teste de Wingate, homens produziram maior potência relativa máxima e média. Não foram observadas diferenças na flexibilidade. No teste de chute único, indivíduos mais graduados chutaram mais rápido do que os menos graduados (200,6±12,3m/s versus 258±5,6m/s; p<0,001) e executam maior número de chutes em 10s (21,6±2,1reps versus 15,5±0,7reps; p<0,001). Conclui-se que há diferenças entre homens e mulheres praticantes de TKD quanto a características antropométricas e motoras, e que atletas mais avançados exibem maior aptidão física geral e específica.*

Palavras-chave*: Artes marciais; Composição corporal; Educação física e treinamento.*

INTRODUCTION

Taekwondo (TKD) is an official combat modality of the Olympic Program[1], and is also part of the Youth Olympic Games program for competitors aged 14-18 years, with five weight categories for each sex. Most studies on TKD are aimed only at general indicators of physical fitness[1,2]. In this context, measurements of anthropometric aspects, strength resistance and muscular power measured by vertical jumps[1] or measured in isokinetic dynamometer[2] are common. From the point of view of the specific evaluation, a recent study described the profile of elite Brazilian athletes in the 10-s kick test[1]. Knowledge on specific fitness is necessary for the proper organization of the training processes, since this is relevant for the good performance in the modality. In TKD, ectomorph profile, lower limb power, as well as well-developed aerobic resistance and anaerobic power are required[2,3]. In general, athletes of both sexes with higher graduation have higher maximum oxygen uptake (VO_2max) and lower fat percentage when compared to less graduated athletes[4]. When comparing age groups, it was observed that younger recreational athletes have lower VO_2max compared to older athletes[5]. However, there is still lack of evaluations considering aspects such as level of experience and sex.

Studies have pointed out that high physical fitness is relevant for success in TKD[1,3-4]. This occurs because in a single championship, there are successive matches, which are structured in fights of two to three rounds from 90s to 120s, with rests of 60s, with intermittent and high-intensity efforts[6]. Since the physical conditioning of TKD athletes is considered as one of the main factors for success in competitive performance[1], the scoring system involves the application of blows to the opponent's trunk and head in high-speed motor actions that generate impacts sufficiently strong to validate the points obtained[6]. As competitions are divided by age, sex and graduation, knowing the physical fitness of TKD athletes from these parameters can contribute to better description of the sporting profile and better knowledge of the sport's demands[1].

It is noteworthy that the greater the speed and power of blows of a fighter, the greater the chances of competitive success[6]. In this sense, the study hypothesis is that sex, age and experience differently affect general anthropometry and physical fitness aspects, while experience and graduation would have greater effect on specific aspects of the modality. Considering the scarcity of studies comparing the general and, mainly, the specific performance of TKD athletes, the aim of this investigation was to evaluate anthropometric variables and general and specific physical performance in TKD athletes according to sex, age group and level of experience.

METHOD

This is a cross-sectional observational study. Athletes and their legal guardians read and signed a free and informed consent form and the study was

approved by the local ethics committee on research with human beings (protocol # 445.796/2013). To carry out the study, forty-five TKD athletes were included: beginners (from the 9th to the 4th gub) and graduates (above the 3rd gub) of both sexes from a municipality in southern Brazil. After clarifications and agreement for participation was obtained, participants scheduled specific days and times for participation in the study. The sample recruitment process took into account accessibility, and all fitness centers and clubs with TKD practices in the city were visited and invited to participate.

Each individual was evaluated in two sessions separated by 72 hours, which took place during the afternoon, two weeks before the main state competition in the first semester of 2014. The same times were scheduled for all individuals, and procedures took place between 02:00 pm and 07:00 pm. To perform physical tests, the five-minute warm-up routine started, consisting of low-intensity run (Borg's subjective perception of effort scale between 13 and 14). Later, athletes went to the collection area, which took place in the sport *dojan*, which was organized for this purpose.

In the first session, anthropometric measurements were performed, followed by warm-up and then strength assessments and anaerobic power test. In the second session, aerobic power, lower limb power and kick speed tests were performed. Each evaluation was carried out by the same and single evaluator, and the data collection team was previously trained. Data were recorded in specific individual forms and later transferred to spreadsheets. The following evaluation procedures were adopted:

Anthropometry

Body mass measurement occurred with subjects wearing only trunks and T-shirt (Toledo® platform scale with 0.05kg precision). Height was measured with bare feet on stadiometer attached to the scale. Skin folds (SF) were measured with scientific adipometer (Cescorf®, previously measured and calibrated) with 0.1 mm precision, according to protocol of Jackson and Pollock[7]. The thickness of pectoral, medioaxillary, triceps, subscapular, abdomen, supra-iliac and thigh SFs was measured. All skin folds were measured three times on the individual's right side and in a rotation system.

General physical performance tests
- **Muscle power of lower limbs (in cm)**

Evaluated with vertical jump test (VJ) with counter movement, using contact mat (Jump System Pro®, CEFISE, Nova Odessa, Brazil). The subject should try to reach the highest height possible while keeping knees and hips extended during the flight phase and hands on waist. Three attempts were allowed for each individual, considering the best result in the analyses. This test has high reproducibility[8], with r greater than 0.86.

- **Strength resistance (maximum number of repetitions)**

Trunk flexion, with abdominal test, and elbow flexion tests were performed for men with their feet on the floor and women with their knees. In both

tests, subjects were instructed to perform as many repetitions as possible in the 60-second period until exhaustion and only correct executions were considered valid. The standardization of both procedures followed specific indications[9].

- **Anaerobic power and capacity and fatigue index**

The Wingate test was used for lower limbs with load of 0.087 kp / kg of body mass for males and 0.086 kp / kg for females[10,11]. The peak power in the 30-second test was considered the anaerobic power, the average power represents the anaerobic capacity and both are presented in absolute mode and relative to body mass. The fatigue index for this test results from the value obtained for peak power, subtracted from the lowest power reached during the test multiplied by one hundred and divided by the peak power. This test shows test-retest reproducibility from 0.88 to 0.99, with values frequently above 0.94 according to Franchini[10]. BIOTEC 2100® cycle ergometer (CEFISE, Nova Odessa, Brazil) was used.

- **Aerobic power (in m)**

Evaluated with level 1 intermittent YO-YO test, and athletes performed, for as long as possible and in a back and forth regime, 20-meter straight runs. Speed was controlled by sound signals produced with standard audio of the protocol and the test was ended when the participant was unable to follow the rhythm imposed by sound signals twice consecutively[12]. As final result of the test, the total number of meters covered by the athlete up to the last run correctly performed was recorded. The distance covered in the Yo-Yo test was transformed into VO_2max using the VO_2max equation (ml / kg / min /) = distance (m) × 0.0084 + 36.4. This test has high reproducibility (r = 0.98) for athletes in intermittent sports[11].

- **Flexibility test (cm)**

The Wells bench (Sanny®, São Paulo, Brazil) was used, and the result was measured from the most distant position that the athlete could reach on the scale with fingertips. The best result was recorded among three executions with annotation to one decimal place[12].

- **Isometric handgrip strength (kgf)**

Isometric handgrip strength was bilaterally evaluated, three times consecutively, with JAMAR® hydraulic dynamometer, considering the highest value of each hand[7]. To perform the test, subjects remained seated, with 90° elbow flexion.

Specific physical performance tests

- **Kicking frequency (maximum number of repetitions)**

The greatest number of kicks on a fixed target (30 kg punching bag) with the dominant leg in a period of ten seconds was recorded[13,14]. The test, called Frequency speed of kick test (FSKT) was performed with subject at self-selected distance from the target. Higher execution speed was re-

quested in each kick, and this evaluation shows test-retest reproducibility greater than 0.76[13].

- **Kicking time (in ms)**

The *Bandal Tchagui* (BT) kick time was measured with the back leg at distance measured under the width of a fighting base between the athlete's front foot and the target. To quantify the application time of kicks, a digital camera (Casio™, model EX-ZR100) was used, which shoots in Full HD using a 240 fps module and analysis in the Kinovea software, as previously conducted and suggested[15].

For statistical analysis, after determining data normality with the Shapiro-Wilk test, data are presented as mean ± standard deviation (SD). For comparisons between means, three-way analysis of variance was applied (ANOVA 3-way: age category (cadet, junior and senior) x sex (male and female) x graduation (beginner and experienced). To estimate the effect size (ES), partial eta-squared (η^2p) values are presented, which are classified as small (0.01), medium (0.06) and large (0.14). When significant differences were found, *post-hoc* Bonferroni was used. Statistical significance was determined when $p < 0.05$ and the SPSS 17.0 software was used in routine analyses.

RESULTS

Forty-five athletes were evaluated, 12 women and 33 men aged 16.4 ± 5.2 years and time of practice of 3.2 ± 3.5 years. Of these, 15.6% were black belts and 84.4% were colored belts, with 20% of them black belt candidates. The anthropometric characteristics of athletes are shown in table 1 and indicate that body mass and height are higher in athletes in the senior category.

In the vertical jump test, differences between sex and graduation are identified, but without interactions, which allows indicating that men

Table 1. Anthropometric characteristics of Taekwondo athletes according to sex and level of experience (N = 45).

	Male				Female				Sex			Graduation			Category		
	Beginner (n= 17)		Experienced (n= 14)		Beginner (n= 11)		Experienced (n= 3)										
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	F	$\eta_z p$	p	F	η^2_p	p	F	η^2_p	p
Body mass (kg)																	
Cadet	51.6	±8.3	54.1	±9.1	49.2	±6.3	51.4	±15.2	0.21	0.001	0.64	0.15	0.01	0.69	10.4	0.39	0.001
Junior	63.3	±11.6	54.7	±11.8	61.7	±8.2	78.4	±30.2									
Senior*	77.9	±25.5	76.2	±4.6	64.9	±3.5	-	-									
Height (cm)																	
Cadet	154.7	±11.2	169.9	±8.1	157	±9.2	161.5	±7.7	4.9	0.11	0.03	0.32	0.01	0.57	5.1	0.24	0.01
Junior	170	±9.6	165.5	±5.9	157	±6.3	162.5	±6.3									
Senior*	180.5	±12.1	176.8	±2.3	161.5	±10.6	-	-									
Sum of skin folds (mm)																	
Cadet	103.3	±37.7	71.7	±37.4	89.5	±16.7	94.1	±6.6	11.1	0.25	0.002	1.1	0.03	0.29	1.3	0.07	0.27
Junior	70.1	±24.8	55.1	±4.7	134.6	±28.6	142.4	±76.5									
Senior	106.1	±49.5	69.8	±16.8	143.4	±43.2	-	-									

Note. * Statistical difference when compared to the cadet category ($p < 0.05$). SD = standard deviation.

jump higher than women (p = 0.003) and experienced athletes jump higher than beginners (p = 0.02; table 2). In the elbow flexion test, difference was found between graduations, with the highest values among more graduated athletes. For abdominal pushups, differences were observed between sexes (F = 8.01; η^2p = 0.20; p = 0.008), and graduations (F = 6.7; η^2p = 0.17, p = 0.01), and interaction between sex and age (p = 0.03) and between age and graduation (p = 0.05) was observed, which indicates that the age group has important effect on this variable. Regarding anaerobic fitness assessed by the Wingate test, differences between sexes (F = 10.3; η^2p = 0.24, p = 0.003) and ages (F = 4.9; η^2p = 0.23, p = 0.01) were observed at maximum power and men in the senior category have higher values when compared to women in the same category and with athletes in the cadet category. For medium power, difference is observed only between sexes (F = 11.7; η^2p = 0.26, p = 0.002), and the same is valid for maximum relative power.

For handgrip, statistical difference between sexes (F = 15.4; η^2p = 0.32, p = 0.001) and ages (F = 8.1; η^2p = 0.33, p = 0.001) was observed for the right side and for the left side (sex: F = 14.7; η^2p = 0.31, p = 0.001; and ages: F = 8.9; η^2p = 0.35, p = 0.01); however, without interaction with graduation, which indicates that the time of practice may not influence handgrip. There were no statistical differences in the flexibility values.

In the maximum aerobic power assessed by the level-1 intermittent recovery Yo-Yo test, difference was observed only between sexes, with higher values covered by experienced athletes of both sexes. Beginners in the male cadet category reached 38.47 ± 1.56 ml / kg / min and graduates in the same category reached 41.19 ± 2.07 ml / kg / min. In females, beginners reached 38.33 ± 0.57 ml / kg / min and graduates reached 38.92 ± 1.18 ml / kg / min. In the junior category, values are 40.01 ± 1.81 ml / kg / min for male beginners, and 41.49 ± 2.13 ml / kg / min for graduates of the same category. In females, 38.16 ± 1.14 ml / kg / min was reached for beginners and 38.08 ml / kg / min for graduates. For the senior category, values are 39.08 ± 1.85 ml / kg / min for male beginners and 41.66 ± 1.18 ml / kg / min for graduates of the same category. In females, values were 37.40 ± 0.48 ml / kg / min for beginners. Higher maximum oxygen uptake values were found for more graduated male athletes when compared to female athletes (p <0.05).

Figure 1 shows the values of the Wingate test. For maximum anaerobic power (W) variables, statistical differences are observed between sexes (F = 11.7; η^2p = 0.26 p = 0.003) and age (F = 4.9; η^2p = 0.23, p = 0.01) without interaction with graduation. For average power, statistical difference was observed between sexes (F = 11.7; η^2p = 0.26, p = 0.002) without interaction between age and graduation. For maximum and relative average power (W / kg), statistical differences were observed when comparing sexes (F = 8.7; η^2p = 0.22, p = 0.006), with no differences for age and graduation (figure 2). These results indicate that graduation does not seem to affect the power of taekwondo athletes in the present sample.

Table 3 presents the results in specific tests of the modality. For the

10-s kick test, there were differences between categories (F = 15.5; η^2p = 0.32, p = 0.001), and the same difference was observed in the kick time test (F = 15.17; η^2p = 0.33, p = 0.001), indicating that more graduated athletes performed better in both tests.

DISCUSSION

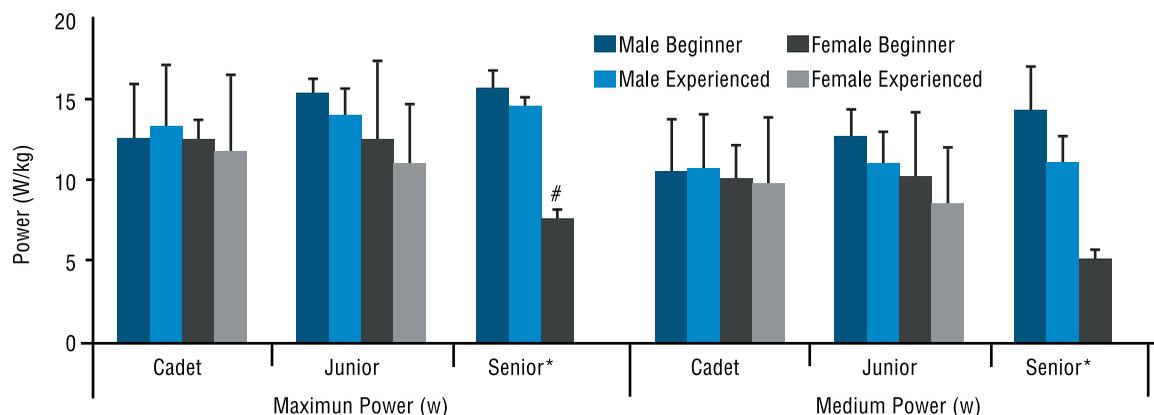The present study aimed to evaluate anthropometric variables and general

Table 2. General physical performance characteristics of Taekwondo athletes according to sex and level of experience (N = 45).

	Male				Female				Sex			Graduation			Age		
	Beginner		Experienced		Beginner		Experienced										
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	F	η^2_p	p	F	η^2_p	p	F	η^2_p	p
Vertical jump (cm)									5.8	0.15	0.02	4.9	0.13	0.03	0.96	0.05	0.39
Cadet	25.7	±6.9	33.0	±6.8	22.6	±3.9	28.9	±8.3									
Junior	34.9	±5.2	38.8	±5.1	22.3	±6.8	29.1	±10.5									
Senior	24.8	±10.1	42.3	±8.5	22.1	±4.3	-	-									
Ground support (reps)									0.11	0.004	0.73	3.99	0.11	0.01	0.29	0.18	0.74
Cadet	15.5	±4.9	25.5	±16.8	19.5	±6.3	31.5	±4.9									
Junior	22.2	±11.5	30.8	±13.0	22.2	±12.6	29.5	±3.5									
Senior	26.0	±11.3	31.6	±5.0	14.0	±1.4	-	-									
Abdominal pushups (reps)									8.01	0.2	0.008	6.7	0.17	0.01	0.54	0.03	0.58
Cadet	32.2	±5.8	4 1.4	±7.6	30.5	±6.8	45.0	±1.4									
Junior	41.5	±3.5	42.3	±5.9	32.7	±7.3	31.5	±3.5									
Senior	37.0	±1.4	44.3	±9.8	22	±1.4	-	-									
Right Handgrip Isometric strength (kgf)									15.4	0.32	0.001	0.88	0.02	0.35	8.1	0.33	0.001
Cadet	24.2	±3.4	30.5	±6.3	22.6	±2.8	23.7	±3.1									
Junior*	40.7	±10.2	38.1	±12.6	27.8	±1.7	29.0	±5.6									
Senior*	42.5	±2.4	48.3	±3.9	23.0	±4.2	-	-									
Left Handgrip Isometric strength (kgf)									14.7	0.31	0.001	0.77	0.01	0.38	8.9	0.35	0.01
Cadet	23.2	±4.7	29.9	±6.1	21.8	±0.3	20.6	±0.5									
Junior*	38.6	±6.6	37.0	±14.5	26.7	±2.5	30.5	±3.5									
Senior*	42.4	±3.6	46.6	±0.5	22.5	±3.5	-	-									
Flexibility (cm)									2.6	0.07	0.11	1.5	0.04	0.22	0.93	0.05	0.4
Cadet	26.0	±4.9	30	±8.7	29.1	±7.1	38.5	±4.9									
Junior	27.6	±2.8	30.5	±6.8	33.2	±10.2	32.0	±5.6									
Senior	22.0	±7.0	25.1	±9.4	27.2	±16.6	-	-									
Distance covered in the Yo-Yo test (m)									14.2	0.3	0.001	4.8	0.13	0.03	0.14	0.009	0.86
Cadet	365.7	±165.6	571.4	±232.9	230.0	±68.3	300.0	±141.4									
Junior	430.0	±114.8	606.6	±233.8	210.0	±132.1	200.0	±113.1									
Senior	320.0	±169.7	626.6	±140.4	120.0	±56.5	-	-									

Note. * Statistical difference when compared to the cadet category (p <0.05). SD = standard deviation.
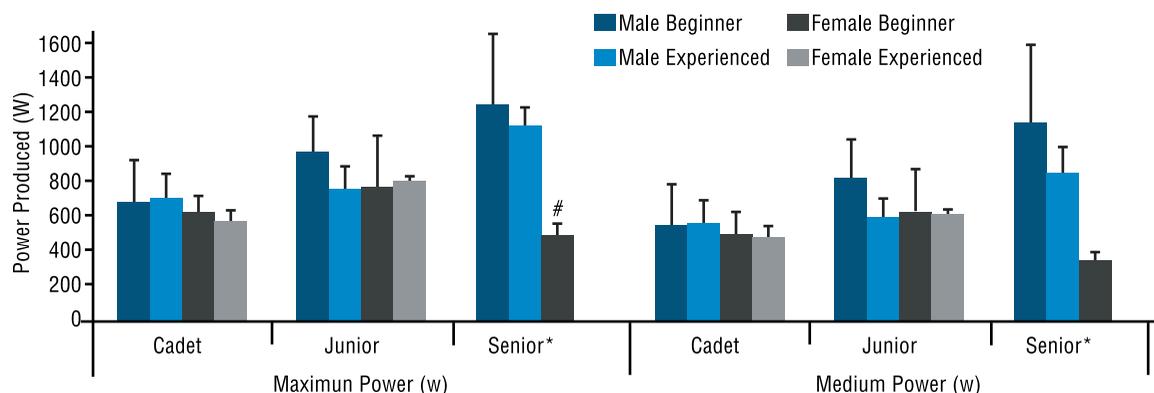
Figure 1. Maximum power and absolute average power in the Wingate test according to category, sex and level of experience.
* Statistical difference when compared to the cadet category (p <0.05). # Statistical difference when compared to males (p <0.05).

Figure 2. Maximum power and relative average power in the Wingate test according to category, sex and level of experience.
Statistical difference when compared to males (p <0.05).

Table 3. Specific physical performance characteristics of Taekwondo athletes according to sex, age and level of experience (N = 45).

	Male				Female				Sex			Graduation			Age		
	Beginner		Experienced		Beginner		Experienced										
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	F	η^2_p	p	F	η^2_p	p	F	η^2_p	p
10-s kick test (reps)									0.98	0.03	0.32	15.5	0.32	0.001	0.14	0.009	0.86
Cadet	16.0	±2.0	19.2	±1.1	15.2	±3.8	19.0	±5.6									
Junior	16.7	±1.7	20.0	±2.0	16.5	±1.2	17.0	±1.0									
Senior	15.5	±0.7	21.6	±2.1	15.5	±0.7	-	-									
Kick time (m/s)									2.02	0.05	0.16	15.7	0.33	0.001	0.19	0.01	0.82
Cadet	254.8	±28.1	233.5	±15	264.2	±22.9	233.0	±29.6									
Junior	251.7	±32.5	212.6	±16.7	265.2	±21.4	237.0	±11.3									
Senior	258.0	±5.6	200.6	±12.3	276.5	±61.5	-	-									

Note. SD = standard deviation

and specific physical performance of TKD athletes and to compare results according to sex and level of experience. Although previous studies have investigated the fitness level of TKD athletes[1,15] and compared results by sex[16], age[17] or training level[18], to the best of our knowledge, this is the first study that considers all these analyses simultaneously. Thus, the main findings reveal that men have differences in relation to women and there

are also differences between categories in anthropometric and general and specific performance variables. The present study also found that the experience in the modality seems to have an important effect on the performance of specific tests.

The body mass of beginner and experienced cadet athletes of the same category was slightly higher than that found in Israelis of the same category[19]. In Malaysian athletes of national competitive level aged 18 years[6], values of 68.29 ± 20.69 kg were found for male athletes and 59.72 ± 10.03 kg for female athletes, but athletes of the present study presented higher body mass. It was found [1] that adult male Brazilian elite TKD athletes present average height of 181.67 ± 8.50 cm, while Malaysian competitors presented 173.90 ± 8.45 cm[18], values close to those found in the present investigation. Regarding body composition, medalists in national and international competitions[20] were evaluated and the sum of pectoral, axillary, triceps, subscapular, abdomen, supra-iliac and thigh skin folds was 52.4 ± 12.4 mm. The sum of pectoral, triceps, biceps, subscapular, axillary, abdomen, suprailiac, thigh and calf skin folds of high competitive level athletes was 75.88 ± 18.20 mm, results similar to the present study with participants of equivalent competitive level. In short, TKD athletes have high stature and low values in the sum of skinfolds, corroborating previous findings about the anthropometric profile for the sport[3].

Competitive performance in TKD is also associated with lower limb power[20]. In a study carried out with recreational level junior athletes[17], jump performance was 51.3 ± 2.8 cm, and in senior athletes, it reached 55.5 ± 7 cm. In this sense, a previous study compared the vertical jump of female medalists (32.8 ± 3.9 cm) and non-medalists (28.7 ± 1.9 cm) and found that, on average, medalists jumped 5 cm more[17]. In the present study, athletes obtained poor performance in the vertical jump test. In females, poor performance in tests involving power can be explained by the fact that, when girls enter the pubertal phase, they tend to increase body fat percentage, while boys increase strength[21], and the results point for the need to improve this variable in the population under study. The relevance of monitoring and improving the power of lower limbs is highlighted, since it can influence competitive success[20].

The Wingate test has been used as an indicator of anaerobic fitness, and anaerobic power is relevant in TKD, since the high-intensity actions that determine competitive success, in general, last from 1 to 5 seconds. In this sense, Taaffe et al.[22] found that in the Wingate test, the absolute and relative maximum power reached by junior male athletes was 675.8 ± 30.7 W and 10.7 ± 0.3 W / Kg, respectively, and the average absolute and relative power for females was 435.5.9 ± 12.3 W and 8.4 ± 0.3 W / kg, respectively. Absolute maximum power of 705.9 ± 20.7W and relative power of 11.3 ± 0.2W / Kg for male athletes of the same category and maximum and relative power respectively of 707.9 ± 14.7 W and 9.0 ± 0.2 W / Kg for females[23,24]. As for this test, athletes in the present study showed better performance compared to values previously found in literature, and

athletes in the senior category showed values statistically higher than the other categories, which can be explained by the intensity and characteristics of the training routines, in addition to the chronological factor.

Flexibility is relevant in TKD, given that it allows the execution of higher and more complex kicks, which are worth more points[16]. Recreational male athletes reach 31.7 ± 9.7 cm in the sit-and-reach test, while more experienced athletes reach 39.1 ± 4.3 cm[18]. However, female Croatians, medalists in international competitions, have flexibility of 54.8 ± 4.5 cm, and non-medalists reach 56.6 ± 5.2 cm[20].

The importance of aerobic fitness in TKD performance is related to the faster recovery capacity of athletes between efforts and combats[10]. International-level Tunisian athletes[15] have VO_2max of 52.2 ± 2.57 ml / kg / min and Perandini et al. [25] found that Brazilian athletes have 51.9 ± 2.9 ml / kg / min. Athletes in the present investigation showed lower values, possibly due to the absence of specific sessions to improve aerobic fitness in their training routine and, in this sense, its improvement during the training period is suggested, since Markovic et al.[20] reported that medalists in world and European championships showed greater cardiorespiratory fitness.

In TKD, abdominal musculature must be well developed, as it helps in rotational movements and in absorbing the impact of kicks throughout the combat[7]. Regarding abdominal resistance, American black belt athletes perform 53.7 ± 3.2 repetitions[26], Puerto Rican Olympic level athletes reach 49.5 ± 6.1 repetitions[27]. When compared to data previously found in literature, athletes in the present investigation have lower abdominal resistance level than expected for elite athletes, which is approximately 50 movements in one minute[26]. As for the upper limbs, which are used in the application of punches, in the elbow flexion test, adolescents perform 25 ± 15 repetitions[6], Olympic level Puerto Ricans reach 52.9 ± 18 repetitions[27] and, in the present study, cadets reached 25.5 ± 16.8 repetitions and more experienced individuals reached 31.6 ± 5 repetitions. As for handgrip, in a study[28], elite female athletes reached 34.25 ± 7.49kgf and male athletes reached 34.28 ± 9.06kgf, performances inferior to junior and senior categories of the present evaluation, but not inferior to the cadet category.

As for specific performance evaluations, in a previous study, elite Brazilian athletes performed 23.90 ± 0.66 repetitions in the 10-s test[1]. Among Italian athletes of regional and international level[29], performance was 20.7 ± 1.6 kicks, although it is indicated that the performance of complex exercise [13] increases the performance to values of 23 ± 5 kicks in 10s. The results of the present study found no difference between categories regarding the number of kicks performed and value similar to that of other studies was found. The results of the present study reinforce the practical applicability of specific tests to discriminate competitive levels in the sport[30]; however, the results of the evaluated sample are below expectations for high level athletes, which suggests that training sessions with exercises aimed at improving power and kicking speed are necessary, especially if associated with plyometric exercises and manipulation of recovery periods[13].

Finally, it is necessary to highlight some limitations that must be considered when interpreting our findings. Among them the cross-sectional design, which does not allow cause and effect inferences. Nevertheless, evidence about the effect of experience on specific performance appear to be consistent with what is expected, and our results can encourage coaches to reinforce attention in specific training sessions. Another limitation refers to the small number of experienced athletes; however, it seems to be difficult to overcome this limitation with the expected pattern of abandonment in combat sports over the practice period.

CONCLUSION

Men exhibited better performance in vertical jumps; more experienced athletes showed greater power in lower limbs. Graduated men and women perform more abdominal pushup repetitions. Older and graduated men and women have greater anaerobic power. Men presented greater anaerobic power. Younger athletes had lower isometric handgrip strength. Young men and adults have higher VO_2max. More experienced athletes had higher VO_2max than beginners. In specific kick time tests, differences between categories and sex were not identified, but graduation differences were rather found.

In general, when considered together, these results indicate that sex, experience and age group do not affect general physical fitness variables in a similar way, and that experience in the modality seems to influence performance in specific tests.

COMPLIANCE WITH ETHICAL STANDARDS

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Conflict of interest statement
The authors have no conflict of interests to declare.
Author Contributions
Conceived and designed the experiments: BFA, AF, FBDV. Performed the experiments: BFA, AF. Analyzed data: BFA, FBDV, VSC. Contributed with reagents/materials/analysis tools: DHF. Wrote the paper: BFA, AF, FBDV, LDC, VSC, RVL.

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