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Neuromuscular and judo-specific tests: Can they predict judo athletes' ranking performance?

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Abstract

Background. The contribution of physical performance to the ranking list position of athletes would provide indications about the importance of monitoring their physical conditioning through neuromuscular and judo-specific tests.

Problem and aim: verify if neuromuscular and judo-specific performance may predict the ranking list position of state-level judo athletes.

Methods. Seventeen judo athletes participated in the study and were divided into two groups according to their state-level ranking position: top 20° (n=8) and positions 21°–38° (n=9). The athletes performed neuromuscular (shoulder external (PT_{EX}) and internal (PT_{INT}) rotation torque, handgrip strength (HGS), vertical jumps (VJs) and judo-specific tests (Uchikomi Fitness Test (UFT), Special Judo Fitness Test (SJFT) and Judogi Grip Strength Dynamic ($JGST_{DIN}$) and Isometric Test ($JGST_{ISO}$). T-test and multiple linear regression were used with the level of significance set at 0.05.

Results. The main results demonstrated significant differences for most neuromuscular and judo-specific tests ($p < 0.050$), higher in the top 20° group than in the 21°–38° group. The $SJFT_{TT}$, $JGST_{DIN}$ and PT_{INT} explained 88% of the variance in ranking position ($p < 0.001$).

Conclusion. Neuromuscular performance (in most tests) in the upper and lower limbs and judo-specific assessments ($JGST_{DIN}$, SJFT total throws, and best series of UFT) differentiated the judo ranking position. In addition, the upper-body strength parameters (PT_{INT} and $JGST_{DIN}$) and anaerobic capacity (SJFT total throws) were the variables that better explained the ranking position.

1. Introduction

The current system of the International Judo Federation (IJF) for the performance classification of athletes in international level competitions is based on the World Ranking List (WRL) [Julio *et al.* 2013]. This ranking system is inspired by the Association of Tennis Professionals (ATP) tennis tour, and it is used to place athletes in specific positions over the competition season, avoiding that the best athletes compete against each other in the first competition phases [Franchini, Julio 2015]. In addition, the main goal of the ranking list is to qualify athletes for the Olympic Games. Federations in several countries have adopted the system proposed by the IJF, which considers the scores obtained in different competition levels (regional, national and international) to classify the athletes during a competitive season.

Some investigations have described the performance obtained from victories and results in judo competitions and its relationship with the ranking position. For example, Franchini, Julio [2015] found that two-year WRL performance and short-term performance (competition performance in the year of the Olympic Games) could predict approximately 24% and 26% of the points at the Olympic Games for female and male groups, respectively. Breviglieri *et al.* [2018] verified that the WRL position could predict 18–27% of the results in the Judo World Championship for senior judo athletes (male and female groups), with lower coefficients of determination for cadet and junior athletes. Another study [Courel-Ibanez *et al*. 2018] investigated Spanish judo athletes and verified that high-ranked female athletes had a higher likelihood of winning and passing to the next stage (the elimination phase), while both high-ranked male and female athletes had a higher likelihood of winning in the quarterfinals of the competitions. Both male and female ranking positions were able to predict 64–72% of the results of athletes [Courel-Ibanez *et al*. 2018].

Considering that the coefficient of determination was higher when predicting national-level competition performance [Courel-Ibanez *et al*. 2018] than when predicting international-level competition performance [Breviglieri *et al*. 2018; Franchini, Julio 2015], it is important to understand which factors may contribute to a better ranking position in judo athletes at lower competition levels. Higher values have already been found in physiological [Drid *et al*. 2015; Franchini, Takito, Bertuzzi 2005] and neuromuscular markers [Drid *et al*. 2015; Sanchez *et al*. 2011] in international-level judo athletes (or medallists) compared to national-level or non-medallist judo athletes. However, no studies have analysed the contribution of physical performance on ranking list position, even though the importance of physical performance to success in judo competitions has been reported [Kons, Ache-Dias, Detanico 2017; Kons *et al*. 2018; Lech *et al*. 2010]. In other sports, Kraemer *et al*. [2017] verified a negative correlation between ranking position and upper-body muscle power (assessed via the medicine ball throw test performance) in tennis players, and Fernandez-Lopez *et al*. [2013] found an inverse correlation between ranking position and estimated aerobic capacity (onset of blood lactate accumulation) in surfers. Thus, it seems that both physiological and neuromuscular performance play an important role in the success during the competitive season, particularly in individual sports.

In judo athletes, neuromuscular performance such as shoulder external/internal rotation strength is important to control the distance between the opponent and provoke his/her fall [Ruivo *et al*. 2012], and muscle power of lower limbs is required to perform throwing techniques, as they involving eccentric and concentric contractions and the use of elastic energy stored in tendons (i.e. stretch-shortening cycle – SSC) [Detanico *et al*. 2015]. Aerobic power and capacity are important to sustain the effort during the entire match (especially long ones) and to recovery short rest periods between efforts [Gariod *et al*. 1995], while anaerobic power and capacity sustain the decisive actions that depend on powerful movements [Franchini, Artioli, Brito 2013]. Recent study has found that physical performance (estimated anaerobic capacity, upper-body strength endurance and lower-body muscle power) explained close to 30% of competitive performance (effectiveness, attack attempts and effective combat time) in official judo matches [Kons *et al*. 2017]. However, these findings are related to isolated matches or competition, and it is still unknown whether and in which magnitude the physical performance determines the ranking list position, as it depends on several outcomes throughout the year.

Understanding the contribution of physiological and neuromuscular performance to the ranking list position would provide indications about the importance of monitoring physical conditioning (through strength and judo-specific tests) throughout the competitive season. Thus, the aim of this study was to verify if neuromuscular and judo-specific performance may predict the ranking list position in state-level judo athletes. We hypothesised that neuromuscular and judo-specific tests will moderately explain the ranking list position, due to an already existing relationship between competition performance and physical fitness.

2. Methods

2.1. Participants

Seventeen male judo athletes participated in this study and were divided into two groups according to the median of the senior ranking list of the Judo Federation of Santa Catarina (JFSC), Brazil: top 20º (n=8, 1 to 20º positions) and positions 21–38° (n=9, 21 to 38 º positions). The top 20º group had the following characteristics: age 20 ± 3 years, 67 ± 17 kg body mass, 174 ± 6 cm height, 12.0 ± 3.2% body fat and 11 ± 3 years of judo practice. The athletes of top 20º group competed in the following weight categories: extra-lightweight (n=1), half-lightweight (n=1), lightweight (n=2), half-middleweight (n=2) and middleweight (n=2). The 21–38° group presented the following characteristics: age 20 ± 3 years, 65 ± 16 kg body mass, 173 ± 5 cm height, 11.6 ± 3.6% body fat and 10 ± 3 years of judo practice. The weight categories of the 21–38° group were: extra-lightweight (n=3), half-lightweight (n=2), lightweight (n=3) and half-middleweight (n=1). The ranking list is available from the JFSC, Brazil [JFSC, 2019]. The ranking list considers the classification obtained in different judo competitions during the competitive season (e.g. international competitions – 200 points for first place, 150 for second place, and so on; national competitions – 150 points first place, 100 points second place, and so on), totalling different scores for each athlete according to the state, national and international levels of competitions. We considered the previous competitive season (i.e. 2018) for the ranking list analysis, which was in effect in the moment the data were collected.

All participants were regularly training 4–5 times per week. The evaluation was carried out before the competitive season in which the athletes were preparing for the competitions at the state level. Participants were selected respecting the following criteria: no reported musculoskeletal disorder or injury that influenced their maximal physical performance, and they were required to have been training regularly for at least 2 years. They were in the competition preparatory phase and, therefore, not in a period of rapid weight loss. All participants received a detailed verbal explanation of the purpose, methods and potential risks/benefits of this study and signed a written informed consent form agreeing to participate. This study was approved by the Research Ethics Committee of the local university, according to the Declaration of Helsinki.

2.2 Design

Data collection was performed over two visits to the laboratory and *dojo* (specific place for judo practice) before the start of the competitive season. First, we provided familiarisation with the judo-specific tests: the Uchikomi Fitness Test (UFT), Judogi Grip Strength Test (JGST) and Special Judo Fitness Test (SJFT). Forty-eight hours after familiarisation, the athletes returned to the laboratory for the assessments. In the first moment, athletes underwent the anthropometric measurements and then the isokinetic protocol was performed to assess shoulder external and internal rotation torques. Fifteen minutes later, athletes performed the vertical jumps (VJs) tests as follows: countermovement jump (CMJ), squat jump (SJ) and continuous jump (CJ) [Bosco, Luhtanen, Komi 1983] with a 10-minute interval between each test. Finally, maximal isometric HGS was collected in the dominant hand. Following a period of 30 min, all participants performed the following judo-specific tests: the isometric and dynamic JGST (15-min interval between the tests), 20 min post-UFT test and finally, after an hour, the SJFT in the *dojo*.

2.3 Anthropometric measurements

Body mass and height of participants were measured with a digital scale (0.1 kg accuracy) and a stadiometer (0.1 cm accuracy), respectively. The equation proposed by Petroski, Pires Neto [2012] was used to estimate the body density of athletes, which considers the sum of four skinfold thicknesses (triceps, subscapular, suprailiac, and medial calf). All measurements were performed before the physical tests by an experienced evaluator (level 1 of the International Society for Advancement in Kinanthropometry). The procedure of three sequential measurements was used for the skinfold thickness, and the average was used for the analysis. Body fat percentage was then calculated using the Siri equation [Siri 1961].

2.4 Neuromuscular tests

Shoulder external/internal rotation isokinetic protocol
Participants were seated on the isokinetic dynamometer (Biodex Multi-Joint System-Pro 4; Biodex Inc, Shirley, NY, USA) chair and stabilised with restraining straps placed around their chest and hips. The athletes' arms were weighted to provide gravity compensation. Shoulder external and internal rotation torques were measured with the arm positioned at 45° abduction. The participants' dominant arms were assessed, and all presented right dominance, according to the writing preference. Based on a reference position (0°) with the forearm in the vertical position, the range of motion was set at 70°. Rotational movements were performed considering 0° as the beginning of internal rotation and 70° as the end of internal rotation/the beginning of external rotation.

Before the evaluation, athletes underwent an initial set of 3–4 submaximal trials to familiarise themselves with the shoulder internal and external rotator concentric actions, which were also used as warm-up exercises for the upper limbs. After a 3-minute passive recovery, participants then performed one set of four maximal shoulder external and internal rotations in concentric/concentric mode at 180°/s of angular velocity. This velocity has been used in previous studies that analysed this same motion in judo athletes [Detanico *et al.* 2015], and this type of movement is considered safe [Ellenbecker, Davis 2000]. All participants were encouraged, through both visual feedback and strong verbal support, to give maximal effort for each action. The torque data were exported from Biodex Medical Systems software (version 4, 2012) and filtered using a Butterworth filter fourth order low-pass at 20 Hz. We considered the highest value (within three trials, with the first trial excluded) of shoulder internal rotation peak torque (PT_{INT}) and shoulder external rotation peak torque (PT_{EXT}) for performance analysis. The reliability of isokinetic torque was calculated by the three trials, and the intraclass correlation coefficient (ICC) was 0.98 and 0.99 for PT_{INT} and PT_{EXT}, respectively.

Handgrip strength protocol
Before the assessment, athletes underwent familiarisation with the handgrip dynamometer (Carci® 225, SH 5001 model) through two submaximal trials. Afterwards, participants were instructed to perform the test with maximal grip effort over 5 seconds in the dominant hand. The evaluation was performed with participants in a standing position with the shoulder flexed at 90° (in the concordance of the gripping phase — *kumi-kata*) and the elbow fully extended, similar to the protocol proposed by Bonitch-Gongora *et al.* [2012]. They performed three trials, with the highest value considered as the test performance result. The ICC was calculated with the three trials and showed a value of 0.97 for the dominant hand.

Vertical jump protocols
Before vertical jump assessments, the participants performed a familiarisation/warm-up period involving 30

seconds of hopping on a trampoline, three series of 10 hops on the ground, and five submaximal countermovement vertical jumps. After a 3-minute resting period, athletes performed three maximal trials of CMJ and SJ, along with 15-seconds of CJ on a piezoelectric force platform (model 9290AD; Kistler, Quattro Jump, Winterthur, Switzerland), which measured vertical ground reaction sampling at 500 Hz. CMJ and SJ were performed in randomised order. CJ was the last test performed in order to avoid potential interference from residual fatigue from other tests.

To perform the CMJ protocol, the athletes started from a static standing position and were instructed to perform a countermovement (descent phase), followed by a rapid and vigorous extension of the lower limb joints (ascent phase). During the jump, participants were asked to maintain their trunk as vertical as possible, with their hands remaining on their hips. The athletes were then instructed to jump as high as possible. In this protocol, the agonist muscles are stretched during descent phase (eccentric) when elastic energy is stored in the muscle-elastic components, and is then used, in the ascendant phase (concentric). In the SJ, athletes started the jump from a static position, with the knees at an angle of about 90º, the trunk as vertical as possible, and the hands on the waist. The jump is performed without any countermovement, i.e. only the concentric phase of the agonist muscles are involved in the movement.

The CJ consisted of maximal continuous vertical jumps (CMJs) performed for 15 seconds. Participants were required to keep the trunk as vertical as possible, and the hands were placed on the hips. Verbal feedback was provided to the participants during the test to encourage them to maintain a knee angle of approximately 90° and maximum performance until the end of the test. We used the mean value of jump height and power output (within three trials) in the CMJ and SJ, and the mean value in the CJ (throughout the 15 seconds) as the test performance result. The reliability of the vertical jump variables was calculated by the three trials of the CMJ and SJ and showed an ICC ranging from 0.97 to 0.99 for all variables.

2.5 Judo-specific tests

Judogi Grip Endurance Strength Test (JGST) assessment
Athletes performed familiarisation involving the grip on the *judogi* sleeve and performed at least three dynamic repetitions and one isometric trial on the *judogi* suspended on the bar 48 hours before the official assessments. Both dynamic ($JGST_{DIN}$) and isometric ($JGST_{ISO}$) versions of the JGST were performed after the familiarisation period (48 hours after). The dynamic evaluation consisted of holding the *judogi* rolled around the bar with the elbow joint at maximal extension and performing elbow flexion, moving the chin above the line of the hands. Athletes were asked to perform the maximal number of repetitions from a fully extended to a fully flexed elbow position as many times as possible. After a 30-minute interval, athletes performed the isometric test, which consisted of sustaining the initial position (elbow fully flexed) for the maximal possible time. The chronometer was stopped when the athlete could no longer maintain the original position. The reliability of the JGST has been assessed in a previous study, presenting an ICC greater than 0.98 for both tests [Franchini *et al.* 2011a].

Uchikomi Fitness Test (UFT) assessment
Athletes performed familiarisation with the UFT 48 hours before the official assessment. An 8-min warm-up composed of falling techniques (*ukemi*) and repetitive arm throwing techniques (*uchi-komi*) was assigned to the athletes. The UFT was developed by Almansba, Franchini, and Sterkowicz [2007] and consists of an intermittent test and lasts 3.43 minutes in total duration (near the duration of a judo match) [International Judo Federation, 2018]. Three judo athletes, two partners to be thrown (*uke*) and one executant (*tori*) of the same weight category, were required to participate in this test. The *tori* performed six sets of *uchi-komi* (each set lasting 20 seconds). The arm static work (traction period) lasted from 6 to 18 seconds over the six sets (increasing 3 seconds per set), interspersed with from 4 to 12 seconds of rest (increasing 2 seconds per set). The *tori* had to perform two different sequences of work: (1) arm isometric exercise—the judo athlete grips the sleeve and performs the reverse of a *judogi* hanging on a high bar and (2) explosive and dynamic exercise—after going down on the fixed bar, the athlete runs toward one of the two *ukes*, executes the *ippon-seoi-nage,* and then runs towards the other *uke* and practices the *sode-tsurikomi-goshi* technique. After this, the athlete performs another set of isometric exercises and so on. The distance between the two *ukes* was 4 metres. The number of repetitive techniques without throwing (*uchi-komi*) in the best two series of the test (a + b) and the total series were considered as test performance results. The ICC for the best series (a + b) and total series were 0.88 and 0.97, respectively [Almansba *et al.* 2012].

Special Judo Fitness Test (SJFT) assessment
The SJFT was proposed by Sterkowicz [1995] and described by Franchini *et al.* [1998]. Firstly, athletes performed 5-minute warm-ups, which consisted of jogging, judo falling techniques (*ukemi*) and repetitive throwing techniques without throwing (*uchi-komi*). Subsequently, three athletes of similar body mass and height performed the SJFT, according to the following protocol: two judokas were positioned at a distance of 6 metres from each other, while the test executor was positioned 3 metres from the judokas to be thrown. The procedure was divided into three periods: 15 seconds, 30

seconds (A), and 30 seconds (B) with 10-second intervals between the periods [Franchini, Del Vecchio, Sterkowicz 2009]. In each period, the executor threw the opponents using the *ippon-seoi-nage* technique as many times as possible. Performance was determined based on the total throws completed during each of the three periods ($SJFT_{TT}$). Heart rate (HR) was measured immediately after the test and then one minute later (Polar® M430 – Kempele/Finland). The index ($SJFT_{INDEX}$) was calculated through the sum of HRs (immediately after the test and one minute later) divided by the total number of throws.

2.6 Statistical analysis

Data were reported as mean and standard deviation (SD). The Shapiro-Wilk test was used to verify data distribution normality. Student's t-test was used to compare the physical performance between groups of judo ranking position. Effect size (ES) was calculated according to Cohen's *d*, [Cohen 1988] and Hopkins [2002] criteria of classification were used: 0.0–0.2, trivial; 0.21–0.6, small; 0.61–1.2, moderate; 1.21–2.0, large; and 2.1–4.0, very large. Additionally, multiple linear regression (backward method with criteria of 0.10 for entry and 0.20 for removal) were used to explain the final ranking position from the performance of neuromuscular and judo-specific tests. To determine the independent variables and avoid the collinearity between them, we considered only one variable of each physical test that presented higher magnitude of correlation (r of Pearson) with the ranking position. To test the collinearity, we considered the variance inflation factor (VIF), tolerance and absolute value of correlation coefficients [Dormann *et al.* 2012]. Thus, all independent variables showed a VIF < 10, which is considered to represent no multicollinearity problems, tolerance > 0.1 (showing acceptable multicollinearity), and absolute values of correlation coefficients < 0.70 [Dormann *et al.* 2012]. The independent variables were: HGS, PT_{INT}, CJ_H, UFT_{A+B}, $JGST_{DIN}$ and $SJFT_{TT}$. The analysis was performed using the Statistical Package for Social Sciences (v.17.0; SPSS Inc, Chicago, IL, USA), and the level of significance was set at 5%. The ES was also calculated using G*Power 3.1.7 software (University of Kiel, Kiel, Germany).

3. Results

Table 1 shows the comparison of neuromuscular tests between the top 20° and 21–38° position groups. Higher values were found in the top 20º group for HGS (moderate effect), PT_{INT} (moderate effect), PT_{EXT} (small effect), CMJ_H (small effect), CJ_H (small effect), and CJ_P (small effect) as compared to 21-38° group. No significant differences were found for SJ_H, CMJ_P and SJ_P (small effect).

Figure 1 shows the comparison of judo-specific tests between the top 20° and 21–38° groups on the judo ranking list. Higher values was found in the top 20º group as compared to the 21–38° group for UFT_{A+B} ($p = 0.039$; ES = 3.61, large effect), $JGST_{DIN}$ ($p = 0.002$; ES = 1.79, moderate effect), $SJFT_{TT}$ ($p= 0.002$; ES = 1.75, moderate effect) and $SJFT_{INDEX}$ ($p = 0.005$; ES = 1.55, moderate effect). No significant differences were found for UFT_{TOTAL} ($p = 0.10$; ES = 0.82, small effect) and $JGST_{ISO}$ ($p = 0.18$; ES = 0.66, small effect) between groups.

Table 1. Comparison of neuromuscular tests between the top 20° and 21–38° position groups.

	Top 20º	21-38º	p	ES
HGS (N)	603.8 ± 123.5	445.3 ± 82.4	0.007	1.45
PT_{INT} (N.m)	84.80 ± 16.62	57.57 ± 17.51	0.005	1.59
PT_{EXT} (N.m)	46.15 ± 11.67	34.75 ± 8.62	0.036	1.08
CMJ_H (cm)	47.55 ± 4.93	42.12 ± 5.53	0.049	1.03
CMJ_P (W)	2117.8 ± 593.8	1660.2 ± 355.4	0.080	0.89
SJ_H (cm)	44.5 ± 3.7	39.7 ± 6.1	0.068	0.90
SJ_P (W)	1690.9 ± 358.3	1381.0 ± 350.6	0.210	0.62
CJ_H (cm)	42.1 ± 4.9	36.3 ± 5.4	0.038	1.10
CJ_P (W)	1895.1 ± 385.6	1459.3 ± 431.1	0.047	1.02

PT_{EXT}: Shoulder external peak torque; PT_{INT}: shoulder internal peak torque; CMJ: countermovement jump; SJ: squat jump; CJ: continuous jump; H: height; P: power; HGS: handgrip strength, ES: effect size.

Table 2. Prediction of ranking position from neuromuscular and judo-specific tests.

	Adjusted R^2	p	Indicator	Standardized coefficients (β)	p
Ranking position	0.88	<0.001	$JGST_{DIN}$	-0.431	0.002
			PT_{INT}	-0.360	0.005
			$SJFT_{TT}$	-0.361	0.006

PT_{INT} = shoulder internal peak torque; $JGST_{DIN}$ = Judogi Grip Strength Dynamic Test; $SJFT_{TT}$ = Special Judo Fitness Test – total throws.

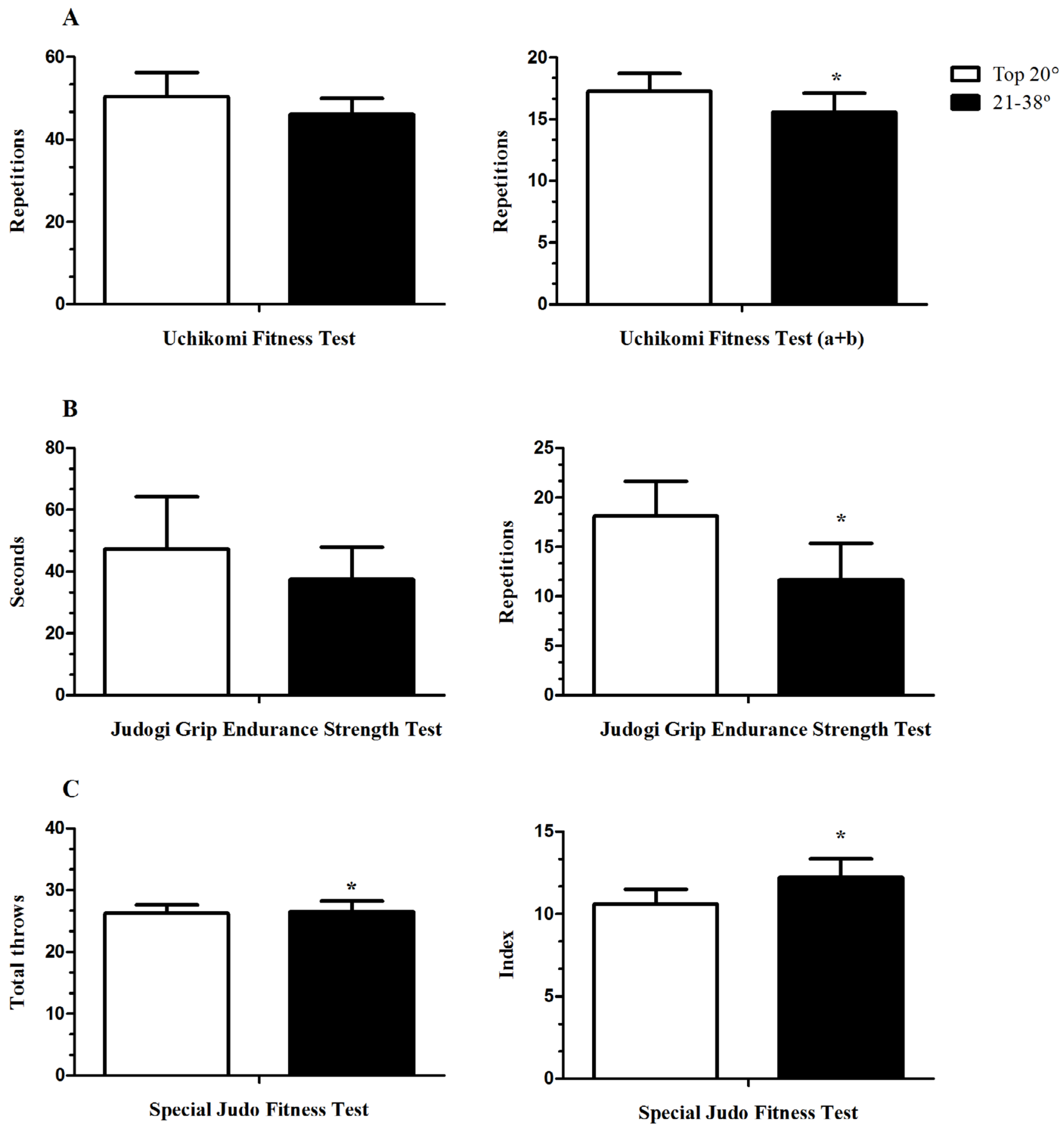

Figure 1. Comparison of judo-specific tests between the top 20° and 21–38° groups. (A) = Uchikomi Fitness Test, (B) = Judogi Grip Endurance Strength Test, (C) = Special Judo Fitness Test.

Table 2 summarises the multiple linear regression to predict the ranking position from neuromuscular and judo-specific tests in judo athletes. It was demonstrated that $JGST_{DIN}$, PT_{IN} and $SJFT_{TT}$ explained 88% of variance in the ranking position.

4. Discussion

This study aimed to verify whether physical performance may predict the ranking list position of judo athletes. The hypothesis of this study was confirmed, since better positioned athletes obtained superior performance in most neuromuscular and judo-specific assessments as compared to athletes who obtained a lower position. Additionally, it was demonstrated that upper-body strength-related parameters ($JGST_{DIN}$ and PT_{IN}) and anaerobic capacity indicator ($SJFT_{TT}$) predicted great part of the results in the final ranking list for judo athletes.

The differences in neuromuscular tests between different ranking positions demonstrated that the best ranked athletes had higher performance for most neuromuscular variables (handgrip strength, shoulder external and internal rotation peak torque and vertical jump performance—CMJ and CJ), showing good discriminant validity for these variables. It was already verified that maximum isometric handgrip strength and vertical jump performance seem to be good indicators of results in state-level competitions, as these variables were correlated with relevant technical actions [Kons *et al.* 2017; Kons *et al.* 2018]. A previous study found that maximum handgrip strength was able to discriminate judo athletes from different positions in competition (i.e. athletes who obtained gold medals presented higher handgrip strength performance as compared to bronze medallists and non-medallists state athletes [Sanchez *et al.* 2011]. Similarly, Drid *et al.* [2015] verified superior values of shoulder external rotation peak torque in elite judo athletes (medallists in international-level competitions) compared to sub-elite athletes (medallists in national-level competitions). This aspect supports that upper-body strength can discriminate judo athletes of different levels, mainly because some skills or muscles involved are similar to those performed in judo-specific actions (e.g. grip on *judogi* and pulling and pushing actions) [Detanico *et al.* 2015].

Considering the performance of vertical jump protocols, only CMJ and CJ differed between the top 20º and 21–38º groups, demonstrating that better ranked athletes seem to present optimization of the SSC during the jump, as SJ performance was similar between the groups, and this test does not involve the SSC (i.e. the performance is dependent upon neural recruitment capacity) [Markovic *et al.* 2004]. The muscle-elastic components, including the SSC, are considered important factors in the ability to generate optimal levels of lower-body muscle power [Komi 2000] and seem to be improved throughout the judo-specific training [Zaggelidis *et al.* 2012]. For this reason, vertical jumps tests involving SSC have been related to better performance in the number of throws in SJFT [Detanico *et al.* 2012], i.e. throwing techniques that require eccentric-concentric phases of the knee flexors and extensors muscles (e.g. *seoi-nage, o-goshi, harai-goshi*).

Analysing the judo-specific tests, our findings showed that better ranked athletes presented higher performance in SJFT (index and total throws), $JGST_{DIN}$ and UFT_{A+B}, demonstrating that these variables seem to have good discriminant validity, unlike $JGST_{ISO}$ and UFT_{TOTAL} (no significant difference between groups). In other studies, similar results for SJFT (total throws and index) [Franchini *et al.* 2005] and $JGST_{DIN}$ [Franchini *et al.* 2011a] have been shown; however, only the UFT_{TOTAL} was previously associated with the performance level (i.e. elite and non-elite) [Almansba *et al.* 2007]. In summary, $SJFT_{TT}$ indicates the anaerobic capacity and $SJFT_{INDEX}$ the ratio between aerobic and aerobic fitness [Franchini *et al.* 2009]. The UFT_{A+B} represents the best two series of the test (judo-specific qualities) [Almansba *et al.* 2007], while the $JGST_{DIN}$ assesses upper-body dynamic strength endurance [Franchini *et al.* 2011a].

Finally, the regression model showed that the $JGST_{DIN}$, $SJFT_{TT}$ and PT_{INT} explained 88% of the variance in the ranking position. This result demonstrated that a possible coupling of upper-body strength-related parameters and anaerobic capacity may be considered good indicators the ranking position of judo athletes. An important finding is that two judo-specific tests (SJFT and JGST) were included in the regression model to explain the ranking position, possibly due to the great ecological validity of the tests variables [Tavra *et al.* 2016], especially regarding the similarity of motor skills [Franchini *et al.* 2005; Lech *et al.* 2010; Franchini *et al.* 2011a], energy system contributions [Franchini *et al.* 2011b] and neuromuscular demand [Lech *et al.* 2010; Detanico *et al.* 2012]. It is noteworthy that other aspects can also be determinant for good positioning in the ranking, such as psychological and technical-tactical parameters, judo competition pathway (key stakeholders) and environment, but these variables were not assessed in our investigation.

Our findings are limited to athletes in state-level competition and should not be extended to high-level judo athletes or other populations of athletes. Future investigations must be conducted relating the WRL with physical and technical-tactical parameters in high-level judo athletes in order to understand the athletes' profiles and the role of these elements in competitive success. Additionally, tracking changes in both physical fitness and ranking position in a larger number of judo athletes may provide a better understanding of the relationship between these two factors.

5. Conclusion

We concluded that neuromuscular performance (in most tests) in the upper and lower limbs and judo-specific assessments ($JGST_{DIN}$, $SJFT_{TT}$ and UFT_{A+B}) differentiated judo ranking position. Furthermore, upper-body strength parameters (PT_{INT} and $JGST_{DIN}$) and anaerobic capacity indicator ($SJFT_{TT}$) were the variables that better explained the ranking position.

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Czy testy nerwowo-mięśniowe przeznaczone dla judo mogą przewidywać wyniki rankingowe judoków?

Słowa kluczowe: sporty walki, wytrzymałość, beztlenowość, wytrzymałość kończyn górnych

Abstrakt

Tło. Wkład wydajności fizycznej decydujący o pozycji na liście rankingowej dostarczyłby wskazówek co do znaczenia monitorowania kondycji fizycznej sportowców za pomocą testów neuromięśniowych przeznaczonych dla judo.

Problem i cel: Celem badania było sprawdzenie, czy wyniki uzyskane w badaniach neuromięśniowych i przeznaczonych dla judo mogą przewidywać pozycję na liście rankingowej zawodników judo biorących udział w zawodach na poziomie krajowym.

Metody. W badaniu wzięło udział siedemnastu zawodników judo, którzy zostali podzieleni na dwie grupy według pozycji w rankingu krajowym: górne 20° (n=8) i 21°-38° (n=9). Wykonano badania neuromięśniowe (rotacja barku zewnętrzna (PT_{EX}) i wewnętrzna (PT_{INT}), siła uścisku dłoni (HGS), skoki pionowe (VJs) oraz testy przeznaczone dla judo (*Uchikomi Fitness Test* (UFT), *Special Judo Fitness Test* (SJFT) oraz *Judogi Grip Strength Dynamic* ($JGST_{DIN}$) i Isometric Test ($JGST_{ISO}$). Zastosowano T-test oraz wielokrotną regresję liniową z poziomem istotności ustawionym na 0,05.

Wyniki. Główne wyniki wykazały istotne różnice w większości testów neuromięśniowych oraz przeznaczonych dla judo ($p < 0,050$), wyższe w górnej grupie 20° niż w grupie 21°-38°. $SJFT_{TT}$, $JGST_{DIN}$ i PT_{INT} wyjaśniły 88% wariancji pozycji w rankingu ($p<0.001$).

Wniosek. Wydajność nerwowo-mięśniowa (w większości badań) kończyn górnych i dolnych oraz oceny testów przeznaczonych dla judo (rzuty całkowite $JGST_{DIN}$, SJFT i najlepsze serie UFT) różnicowały pozycję rankingową judo. Ponadto parametry wytrzymałościowe górnych partii ciała (PT_{INT} i $JGST_{DIN}$) oraz wydajność beztlenowa (rzuty SJFT ogółem) były zmiennymi, które lepiej wyjaśniały pozycję rankingową.