© *Idōkan Poland Association*
"IDO MOVEMENT FOR CULTURE. Journal of Martial Arts Anthropology",
Vol. 19, no. 2 (2019), pp. 41–55
DOI: 10.14589/ido.19.2.7

KINESIOLOGY & COACHING

Sasa Krstulovic[1(ABCDEF)], Goran Kuvacic[1(ABCDEF)], Marko Erceg[1(BEF)], Emerson Franchini[2,3(ACDEF)]

[1] Faculty of Kinesiology, University of Split, Split (Croatia)
[2] Martial Arts and Combat Sports Research Group, Sport Department, University of Sao Paulo (Brazil)
[3] Combat Centre, Australian Institute of Sport (Australia)
Corresponding author: Goran Kuvacic, PhD
Faculty of Kinesiology, University of Split
Teslina 6, 21000 Split, Croatia
Phone: 00385951979970, e-mail: gorkuv@kifst.hr
ORCID: 0000-0001-5302-7192

Reliability and Validity of the New Judo Physical Fitness Test

Submission: 14.10.2018; acceptance: 27.11.2018

Key words: combat sports, field testing, physiological capacities, motor skills, assessment

Abstract
Background. Evaluation of athletes is a key element of the training process. Although there are some judo-specific tests, none of them includes the main judo actions (gripping, throwing, and groundwork) in its structure.
Problem and aim. To evaluate the reliability, usefulness and validity of a new judo physical fitness test (JPFT), which includes gripping, throwing, and groundwork actions.
Methods: Ten male judo athletes (16.5±0.5 years, height = 181.0±7.7 cm, body mass = 78.3±11.5 kg) performed the JPFT twice, separated by 48 h. Validity was determined by examining the relationship between JPFT and the Wingate test, Special Judo Fitness Test (SJFT), simulated judo match (SJM) and incremental exercise test (IET).
Results. All ICC values were statistically significant, except for the number of techniques in series A and the rating of perceived exertion (RPE,) with two variables presenting significant reliability (resting blood lactate, [La], number of techniques in series B), six very significant reliability ([La] 5-min after the test, peak [La], heart rate, HR, 1-min after the test, number of techniques in series C, total number of techniques, JPFT index), and three nearly perfect reliability ([La] 3-min after the test, HR after the test, SJFT index). Large and very large correlations were observed between [La] and HR in the JPFT and those in the SJFT and SJM. The similarity of effort during an official match was correlated with [La] 5-min after the test (r=0.84) and peak [La] (r=0.71) and RPE (r=0.68) to the JPFT.
Conclusions. The JPFT has similar physiological requirements as those typically observed during match simulation and other judo-specific tests. Therefore, this test can be used to monitor the physiological adaptation of judo athletes.

Introduction

Judo match is a high-intensity intermittent grappling combat sport, with high physiological demand. The total judo match duration is 4-min, in which maximal and sub-maximal intensity periods are exchanged in the standing and ground position (20-30 s) with pause periods (5-10 s) [Miarka *et al.* 2014]. Marcon *et al.* [2010] observed that the grip dispute time represented 49±10% to 56±9% of total effort time, whereas data from Miarka *et al.* [2012] allow us to estimate that this phase represented approximately 58% of all standing combat time and 28% of the whole combat time (i.e., pauses included). Typically, around 25% of the valid judo match time is spent groundwork actions [Castarlenas, Planas 1997]. Recently, it was estimated that judo matches lasting between 1-min and 5-min are predominantly oxidative, but that the scoring actions are supported by the phosphagen and glycolytic energy systems [Julio *et al.* 2017]. In general, the assessment of physical fitness is very important because it provides information on the current state of athlete's abilities, which allows the determination of parameters necessary to be improved to allow athletes to reach their maximum competitive performance [Bangsbo *et al.* 2006].

Sports-specific tests are becoming more and more popular in top-level sports and are designed to simulate official sports situations to the greatest extent possible [Uljevic, Spasic, Sekulic 2013]. The prevailing opinion is that the sport-specific tests are more appropriate than

general fitness tests not only for the assessment of specific sports performance of top athletes [Meckel, Machnai, Eliakim 2009], but also in the selection and orientation of young athletes [Sattler *et al.* 2012]. So far, several different judo-specific tests have been proposed, whose common characteristic is to evaluate mixed aerobic and anaerobic profiles of judo athletes [Almansba *et al.* 2012; Lidor *et al.* 2006; Sterkowicz, 1995]. Of all the judo specific tests, the Special Judo Fitness Test (SJFT) proposed by Sterkowicz [1995] has been reported as the most used test to evaluate judo athletes. It was found that the SJFT mainly evaluates athletes' phosphagens system, which can be considered to be the most predominant system contributing to the scoring actions performed in the match [Franchini *et al.* 2011]. Furthermore, classificatory tables are proposed for males and females as well as for certain age categories [Agostinho *et al.* 2018; Franchini, Vecchiio, Sterkowicz 2009; Sterkowicz-Przybicien, Fukuda 2014]. It was also found that using this test can effectively discriminate elite from non-elite male [Franchini *et al.* 2005] and female [Tavra, Franchini, Krstulovic 2016] judo athletes.

However, the main problems of this test to simulate judo match demand are the inclusion of non-specific actions (i.e. running sprints), the absence of strength-endurance actions involved during the judo grip dispute and the lack of groundwork actions. In this experiment, we developed the judo physical fitness test (JPFT), a test that has all the essential elements of the judo (throwing and ground techniques) and faithfully reflects the physical regimen and dynamics of the typical judo match (i.e. the work and rest ratio, dynamic and isometric strength-endurance action involving gripping the *judogi*), while decreasing considerably the sprint running phase. Therefore, the main objective of the present investigation was to test the reliability and validity of this new judo physical fitness test that was elaborated to simulate the requirements of a typical judo match.

Methods

Experimental overview

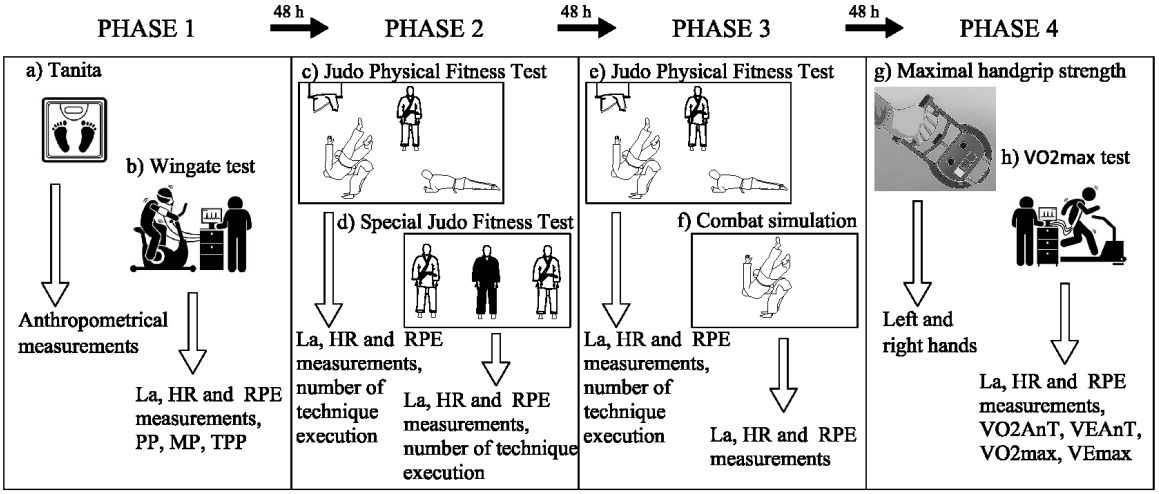
This was a reliability and validation study where the new judo-specific test, the most used judo-specific test (i.e. SJFT), aerobic (i.e. graded exercise test) and anaerobic tests (i.e. Wingate test), as well as a simulated judo match, were used in the validation process. Additionally, the new test was executed twice by each athlete to test its reliability. A new Judo Physical Fitness Test was created to simulate all judo match's demands (i.e. muscle power and repeated sprint ability during throwing techniques, strength-endurance during grip disputes and muscle power during groundwork actions). Moreover, to evaluate the results in such test, a mathematical formula based on the total number of executed techniques, maximum heart rate, and recovery time was proposed.

The experimental design and order of measurements are presented in Figure 1. On the investigation days, all athletes were free from any impediment that could prevent maximal effort during testing. They were requested to abstain from drinking caffeine-containing beverages, drugs, vitamins or supplements and low-fibre diets for 24 h before and during the investigation to reduce any interference on the testing. Also, they were asked to avoid any physical activity 48-h preceding and during the investigation. All tests were performed in the morning, starting at 8 am to avoid any circadian variations [Drust *et al.* 2005].

With investigation aims, four testing phases were developed, Figure 1 represents a testing protocol with measurements. In all phases, the testing was conducted by professionals, members of the Faculty of Kinesiology, University of Split along with the certified medical technician. First and the last phase were conducted in Sports Performance Laboratory (University of Split), with an average ambient temperature of ~23°C inside the laboratory. Second and third phases were performed at local judo club with an average ambient temperature of ~25°C inside the club. Before any testing, participants were familiarized with testing procedures, and verbal encouragement was consistently given to all participants during the tests. The participants were in the preparatory period during the investigation.

Participants

Ten (n=10) high-level male cadet judo athletes (mean ± SD: age =16.5 ± 0.5 years; body height = 181.0 ± 7.7 cm; body mass = 78.3 ± 11.5 kg; body fat (%) = 15.1 ± 2.9; body mass index (BMI) = 23.8 ± 2.2 kg/m^2) of cadet age category (U 18) from Croatia volunteered to participate in this study. The sample size is similar to previous investigations analyzing the reliability of judo-specific tests [Almansba *et al.* 2012; Santos *et al.* 2010]. Athletes participated in the Croatian Cadet National Championship in 2018 in the following weight categories: -66, -73, -81, -90, -100 kg, and were ranked from first to fifth places. Written consent was obtained from the athletes' parents/guardians after being thoroughly informed about the purpose and potential risks of this investigation. Each participant could withdraw from the investigation at any time without any consequence. The Ethical Committee of the Faculty of Kinesiology, University of Split (number: 2181-205-02-05-18-008; 18 June 2018) verified that this investigation complied with 1975 Declaration of Helsinki ethical principles for scientific investigations involving human participants. To participate in this investigation, athletes had to fulfill certain criteria: (i) being healthy (absence of cardiovascular or pulmonary disease, pain, illness, injury or metabolic syndrome symptoms) and clear of any drug-related consumption, (ii) having a valid sport medical certification signed by a sports medicine



La = blood lactate; HR = heart rate; RPE = rating of perceived exertion; PP = peak power; MP = mean power; TPP = time to reach peak power; VO_{2max} = maximal oxygen consumption; VO_2AnT = oxygen consumption at anaerobic threshold; VEAnT = ventilation at anaerobic threshold; VEmax = maximal ventilation.

Figure 1. Schematic representation of the experimental design and order of measurements.

specialist, (iii) participation in at least 80% of the training sessions during the past year. Athletes had (mean ± SD) 8.2 ± 1.3 yr. of judo experience and trained at least five times per week for 1.5 hours per session with average weekly training volume of ~15 h. Their training program consisted of judo technical-tactical and physical conditioning sessions with regular participation on judo tournaments. Training volume, training load, recovery and nutrition was controlled by a professional judo coach.

Procedures

During the first phase of testing anthropometric characteristics (body height, body weight, body fat and body mass index (BMI)) were assessed. After anthropometric measurements, athletes performed Wingate Anaerobic Test (WAnT). On the second phase, athletes performed the JPFT. After completion of the JPFT, athletes performed SFJT with two hours of rest between them to ensure enough recovery. During this phase, the order of performing was always the same, e.g., the first judo athlete who performed the JPFT was the first one to perform the SJFT. In this way, every athlete had the same time of recovery. The second trial of the JPFT (retest) was conducted in the third phase of the investigation. Athletes also performed 4-minute simulated judo match (SJM) after successful completion of the retest. As in previous testing day (phase 2), two hours of rest between tests was ensured for the full recovery with same performance order. In the final fourth phase, athletes first have undergone the maximal handgrip strength testing using the Takei A5401 (Takei, Japan) digital dynamometer with 1-kg precision. The dynamometer was adjusted according to the size of the athlete's hand. Every athlete had a task of generating as much force as possible by squeezing right and left arm three times, separately. Highest value obtained was used as the measure of maximal handgrip strength. After maximal handgrip strength testing, participants performed an incremental exercise test (IET) to volitional exhaustion.

The Judo Physical Fitness Test. A visual representation of the JPFT is displayed in Figure 2. Before the start of the JPFT, athletes performed 25 min warm-up consisting of 8 min of running at 80–100%, 110%, and 125% of lactate threshold intensity (4, 2.5, and 1.5 min respectively), 2 min of executing judo throwing techniques (three sets of 10 repetitions of the *ippon seoi nage* used during the test with 30 s interval between the sets), 2 min of executing choking technique *yoko sankaku jime*, 3 min of stretching. The test is performed on judo tatami wearing standard judogi. For the performance of this test, it is necessary to have *judogi* hanging in a high bar and four judokas of the same weight category, of which three judokas (*uke*) assist one executor (*tori*). Four markers are placed at a distance of 1.5 meters from the specified centre of the test area. The two *uke* are placed opposite each other (at a distance of 3 meters), while the third one lies on the chest opposite the *judogi* at the high bar (also at a distance of 3 meters). The procedure is divided into three 30 s periods of work with 10-s intervals of rest among them. Each working interval is comprised of 10 s of *judogi* grip (judoka grips the reverse of a *judogi* with stretched hands) and 20 s of intermittently executing the *ippon Seiko nage* throwing technique and the *yoko sankaku jime* choking technique. During the rest interval, athletes stand under the judogi in the hanging bar and prepare for the next period. At each period, the sequence of task execution is identical. Thus, the athlete first performs isometric work with arms and then clockwise performs the intermittent techniques as many

times as possible on the preferred side. Ultimately, the number of execution (*ippon seoi nage* and *yoko sankaku jime*) of each series is added. Additionally, immediately and 1 minute after test completion, the athlete's heart rate is checked. The success in the test is calculated using the following formula:

$$Index(beats \cdot min^{-1} \cdot execution^{-1}) =$$

$$= \text{n x } \frac{HR1(beats \cdot min^{-1}) - HR2(beats \cdot min^{-1})}{HR1(beats \cdot min^{-1})}$$

Legend: n= number of successful executions (*ippon seoi nage* and *yoko sankaku jime*), HR1- heart rate immediately after testing, HR2 - heart rate 1-min after testing

(*You can see a video example here https://viscometer/283189319)*

Also, performance is determined according to formula used in SJFT (formula in the description of the test)

Special Judo Fitness Test.

Following a 25 min warm-up consisting of 8 min of running (4 min at 80–100% of lactate threshold intensity, 2.5 min at 110% of lactate threshold intensity, and 1.5 min at 125% of lactate threshold intensity), 6 min of stretching (with emphasis on quadriceps and hamstrings), 2 min of executing judo throwing techniques (three sets of 10 repetitions of the technique used during the test with 30 s interval between the sets), 3 min of stretching, athletes performed the SJFT proposed by Sterkowicz [1995]. After an adequate warm-up, three judo athletes of similar body mass and height enter the testing area on judo tatami. Judo athletes performed the SJFT according to following protocol as previously described [Detanico *et al.* 2012]: two judokas (*uke*) were positioned at 6 m distance from one another, while the test executor (*tori*) was 3 m from the judokas that would be thrown. The procedure is divided into three periods: 15 s (A), 30 s (B), and 30 s (C) with 10-s intervals between them. During each period, the executor throws partners using the *ippon seoi nage* technique, as many times as possible. Immediately and 1 minute after test completion, the athlete's heart rate is checked. Performance is determined by the total throws completed during each of the three periods (A + B + C) and the index of the test was calculated according to the following formula:

$$Index\ (beats \cdot min^{-1} \cdot throw^{-1}) =$$

$$= \frac{HR1(beats \cdot min^{-1}) + HR2(beats \cdot min^{-1})}{n}$$

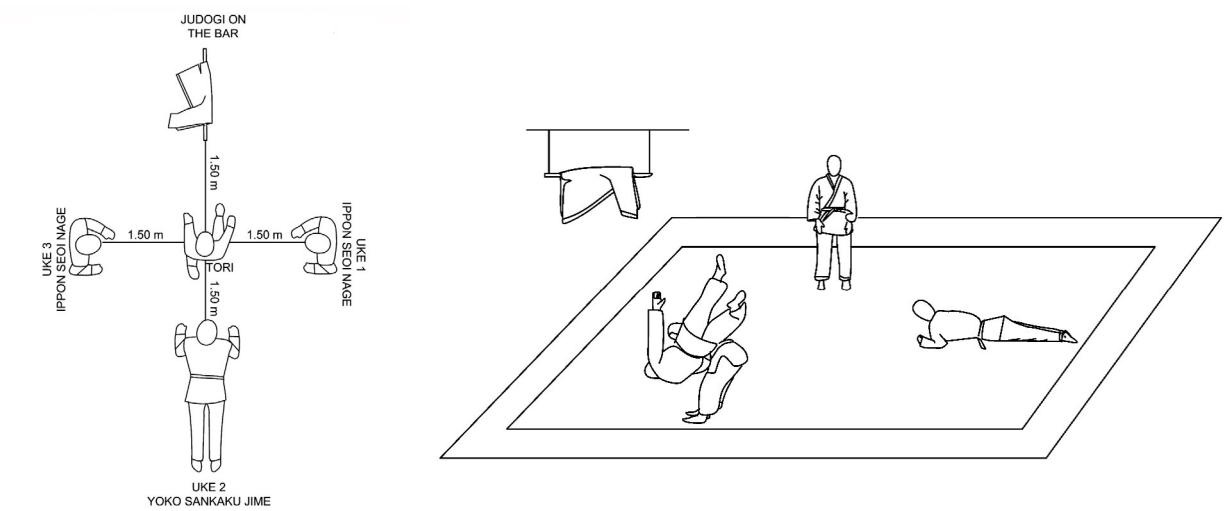
Legend: n= number of successful executions (*ippon seoi nage*), HR1- heart rate immediately after testing, HR2 - heart rate 1-min after testing

Simulated Judo Match.

Before any match, the athletes were informed about the procedures. To simulate judo match, judo athletes of equivalent weight category were divided into pairs to perform a 4-min match, regardless of *ippon* occurrence. Athletes performed a 15 min general warm-up (50%–60% maximum heart rate) composed of jogging, walking and stretching [Tomaras, MacIntosh 2011] with additional judo specific exercises (shadow *uchi-komi*), gymnastic exercises and fall simulations. Warm-up was similar to what is done before randori training or competition. Official Croatian Judo Federation judge was recruited to conduct the matches.

Wingate Anaerobic Test.

WAnT was performed on a cycle-ergometer (Monarch, Peak Bike 894e, Monark, Sweden) with procedures used



Panel A Panel B

Figure 2. Visual representation of the Judo Physical Fitness Test (JPFT) from above (Panel A) and a side view (Panel B).

by Sbriccoli *et al.* [2007]. Before the start of WAnT, athletes performed a 15 min general warm-up (50%–60% maximum heart rate) composed of jogging, walking and stretching [Tomaras, MacIntosh 2011]. Following the adjustment on cycle-ergometer according to their length leg and the distance of the handlebar [Padulo *et al.* 2015], athletes started WAnT with a 5-minute warm-up pedalling at a self-selected pace. Then participants were asked to perform two "all-out" sprints (4–8 seconds) followed by a 5-minute rest. WAnT was performed at maximal intensity for 30-s with a load corresponding to 7.5% of body mass. When resistance was applied after 3-s with no load, athletes were instructed to pedal with maximal intensity for 30 s. When the test finished athletes had to pedal 1 minute against reduced resistance followed by a 1 min passive recovery phase with no load. Using the Monark Software (Monark ATS Software, Monark, Sweden) the following variables were obtained: peak power (PP), mean power (MP), relative peak power (PPr), relative mean power (MPr), time to peak (TPP).

Incremental Exercise Test.

IET was performed on a treadmill H/P/ Cosmos pulsar (H/P/Cosmos Sports & Medical, Nussdorf-Traunstein, Germany) using previously validated portable telemetric metabolimeter system Cosmed K5 (Cosmed K5, Cosmed S.r.l., Italy) [Gao *et al.* 2018] with following parameters calculated (measured and recorded breath-by-breath): oxygen consumption at anaerobic threshold (VO_2AnT), pulmonary ventilation at anaerobic threshold (VEAnT), maximal oxygen consumption (VO_{2max}), maximal pulmonary ventilation (VEmax). The anaerobic threshold was determined by means of a gas exchange (V-slope method - the intersection of the slope of VCO_2 and VO_2) [Beaver, Wasserman, Whipp 1986]. (Cosmed K5 uses a face mask that covers both the mouth and the nose to collect expired gas from the participants. The heart rate was determined using GarminTM as a standard addition to the metabolimeter. Before each participant, the gas analyser was calibrated using a high-precision gas mixture (5.06% CO_2 and 16.02% O_2) and the spirometer with a 3- litre syringe (Hans Rudolf, Kansas City, MO, United States). Protocol of testing included following [Santos *et al.* 2011): starting velocity of 5 $km.h^{-1}$, velocity increments of 2 $km.h^{-1}$, effort stages of 3-minutes, treadmill inclination of 5% (constant), and pause of 30 s between stages. At least two of the following criteria had to be met in order to consider that VO2max has been achieved: respiratory exchange ratio higher than 1.1, blood lactate concentration higher than 8 $mmol/L^{-1}$, changes in VO2 lower than 2 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ despite increments in the intensity and a heart rate ±10 bpm of the maximal predicted heart rate [Howley, Bassett, Welch 1995]. Duration of the test was dependent on participant's volitional exhaustion. When the test was finished, participants were instructed not to stop running abruptly, but to maintain running at a slower velocity (velocity corresponding to 8 $km.h^{-1}$ for 2 min).

Anthropometrical Measurements.

Body height was measured with Harpenden Portable Stadiometer 603 VR (Holtain LTD, Crosswell, UK). Body mass, body fat and BMI (body mass in kg/ height in m^2) were analysed by the Tanita diagnostic scale (BC 418) [Neovius *et al.* 2006]. Standardized conditions regarding the previous exercise, dietary intake and skin temperature were respected [Kyle *et al.* 2004). All measurements were taken by the same experienced researcher.

Rating of Perceived Exertion.

In this investigation, we used Borg Category Ratio-10 (CR-10) RPE scale to quantify participants perceived exertion. Recently, Bromley *et al.* [2018] have reported that RPE can be used across a range of competitive levels and genders to monitor the workload of mixed sessions and individual randori in judo. Borg Category Ratio-10 (CR-10) RPE scale was used in following tests: WAnT, JPFT in both trials, SJFT, SJM (4 min), and IET. Verbal description of the scale was made before each test. At the end of each test, athletes were given a full view on the scale and were asked to rate their perceived exertion. Obtained values were classified according to the American College of Sports Medicine qualitative descriptors.

Likert Scale for Effort Similarity.

Athletes were asked to report the extent of similarity in effort between the newly constructed JPFT and the SJM conducted in this investigation. The same was done concerning the official judo match. The following question was asked: "*How similar is the effort in this new test compared to the simulated judo match and the official judo match? Please indicate the extent to which you agree or disagree with the following: 1) The effort in the new test is the same as that in the simulated judo match; 2) The effort in the new test is the same as the typical effort in an official judo match.* For this purpose, we used a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree)

Physiological Measurements.

Physiological measurement included lactate concentrations ([La]) and heart rate (HR). Arterialized blood samples (20 µL) were collected from the earlobe at rest and after 3rd, and 5th min in the recovery phase for the following tests: WAnT, JPFT in both trials, SJFT, SJM (4 min), and IET. To determine Lactate concentrations, a portable analyser Roche Accutrend Lactate Plus System (Roche Diagnostics, USA) was used and calibrated before each measurement according to the manufacturer's manual. HR was continuously recorded by heart rhythm monitor (Polar S810, OY Finland) and values immedi-

ately, percentage of maximal HR, and 1-min post-test were obtained for the following tests: WAnT, JPFT in both trials, SJFT, and SJM (4 min). As previously described, HR in IET was recorded with GarminTM, as this system is integrated with the gas analyser.

Statistical Analysis

Data were analysed using Statistica for Windows (Statsoft, version 8) and are presented as mean and standard deviation or median and interquartile intervals. The homogeneity of variances and the normality of the sample were tested using Levene's test and the Shapiro-Wilk's test, respectively. For variables that these assumptions were met a paired Student t-test was used to compare test and re-test physiological responses and performance, and the effect size was determined using Cohen's d [Cohen 1988], with values of <0.2, >0.2 and <0.6, >0.6 and <1.2, >1.2 and <2.0, and ≥2.0 considered as trivial, small, medium, large, and very large effects, respectively [Hopkins *et al.* 2009]. Otherwise a Wilcoxon matched pairs test was used, and effect sizes were calculated as $r = Z/\sqrt{n}$. Intraclass correlation coefficient (ICC), typical error (TE), typical error expressed as coefficient of variation (CV%) were calculated to determine absolute and relative reliability, and the 95% confidence interval was also presented. ICC values were classified according to Hopkins [2018]. Smallest worthwhile change (SWC) was also calculated for various effect sizes (0.2, 0.6, and 1.2 multiplied by the between-participants' standard deviation, based on the Cohen's effect size principle, for small, medium, and large effect sizes, respectively) and the usefulness of each variable in both studies was assessed by comparing the SWC score with the TE [Hopkins, Schabort, Hawley 2001]. Thus, if the TE was higher than SWC, the evaluation of the variable being used was "marginal;" if the TE was similar to the SWC, it was "medium;" and if TE was less than the SWC, and evaluation of "good" was given to the test to detect small (0.2), medium (0.6), and large (1.2) differences. In addition, the minimal detectable change (MDC) was also calculated (TE x 1.96 $\sqrt{2}$) and interpreted as the minimal change required in a given variable to the coach or sport scientist to be confident that a real change has occurred [Hopkins 2018]. The validity has been established by assessing the relationship between variables using a Pearson product moment correlation coefficient (r) associated with the coefficient of determination (R^2). The magnitude of the correlations was also determined using the modified scale by Hopkins [2000]: r , 0.1, trivial; 0.1–0.3, small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; .0.9, nearly. For significance testing, alpha was set at $p < 0.05$.

Results

Physiological and performance parameters measured during the IET showed that athletes achieved a VO_{2max} of 53.51 ± 6.31 ml·kg^{-1}·min^{-1}, a maximal HR of 200 ±6 bpm, while [La] was 13.49 ± 1.71 mmol.L^{-1} at 3-min and 11.93 ± 7.79 mmol.L^{-1} at 5-min of recovery.

Table 1. Performance and physiological responses to the Special Judo Fitness Test (SJFT) and to the Wingate Test.

Variable	SJFT	WAnT
Resting blood lactate (mmol/L^{-1})	1.76 ± 0.45	1.8 ± 0.32
Blood lactate 3-min after the test (mmol/L^{-1})	16.25 ± 2.49	13.61 ± 1.79
Blood lactate 5-min after the test (mmol/L^{-1})	15.15 ± 2.64	13.52 ± 1.33
Peak blood lactate (mmol/L^{-1})	16.43 ± 2.46	14.14 ± 1.56
Heart rate after the test (bpm)	189 ± 6	180 ±3
Heart rate 1-min after the test (bpm)	171 ± 7	NM
Number of throws in series A (rep)[a]	6 (6;6)	NM
Number of throws in series B (rep)[a]	11 (11;12)	NM
Number of throws in series C (rep)[a]	10 (10;11)	NM
Total number of throws (rep)	28 ± 2	NM
Index (bpm/rep)	12.98 ± 0.87	NM
Peak power (W)	NM	779 ±159
Relative peak power (W/kg)	NM	9.91 ± 0.81
Mean power (W)	NM	585 ± 102
Relative peak power (W/kg)	NM	7.48 ± 0.51
Time to reach peak power (s)	NM	3.7 ± 1.2
Rating of perceived exertion (a.u)[a]	9 (9;9)	7 (7;7)

Values are mean and standard deviation, unless marked otherwise; NM = not measured; [a]Non-normal distribution variables: median values (lower and upper quartile).

Table 1 presents the performance results during SJFT and WAnT.

Table 2 presents the test-retest results of the JPFT.

[La] pre-test (t_9 = 3.34, p = 0.009) and 5-min post-test (t_9 = 2.39, p = 0.040) were higher in the test than in the re-test. Similarly, HR immediately after the test (t_9 = 3.14, p = 0.012) and 1-min after the test (t_9 = 2.83, p = 0.020) were higher in the test than in the re-test. Less repetitions were performed in set 1 in the test compared to re-test (Z = 2.37, p = 0.018), and a lower RPE was observed after test compared to re-test (Z = 2.20, p = 0.028). The index SJFT was higher (t_9 = 3.52, p = 0.007) in the test than in the re-test. No other significant differences between test and re-test were found (p > 0.05).

Table 3 presents measures of reliability and usefulness of physiological and performance responses to the JPFT.

On the Likert scale for the similarity between the effort in the JPFT and the SJM effort, one athlete attributed 5, while six athletes reported 4 and three reported 3. When asked about the similarity between effort in the JPFT and the effort in an official match, one athlete attributed 5, eight athletes 4 and one athlete 3.

Table 4 presents the significant correlations between JPFT and the four performance tests and Likert scale for the effort similarity

Discussion

The main findings of our study were: (a) there were significant decreases in the re-test compared to the test for [La] pre- and 5-min post-test, HR after and 1-min after the test, but athletes increased the number of throws in the first set and reported higher RPE in the re-test compared to test. Consequently, the SJFT index was worse in the test compared to re-test; (b) all ICC values were statistically significant, except for number of techniques in series A and RPE, with two variables presenting large reliability, six very large reliability, and three nearly

Table 2. Performance and physiological responses during test and re-test of the Judo Physical Fitness Test.

Variable	Test	Re-test	ES(95% CI)
Resting blood lactate (mmol/L^{-1})	1.89 ± 0.44**	1.53 ± 0.33	0.98 (0.81 to 1.14)
Blood lactate 3-min after the test (mmol/L^{-1})	14.54 ± 2.17	14.38 ± 1.82	0.08 (-0.74 to 0.91)
Blood lactate 5-min after the test (mmol/L^{-1})	14.02 ± 1.93*	13.22 ± 1.31	0.51 (-0.17 to 1.20)
Peak blood lactate (mmol/L^{-1})	14.73 ± 2.09	14.45 ± 1.71	0.15 (-0.64 to 0.95)
Heart rate after the test (bpm)	187 ± 6*	184 ± 7	0.50 (-2.11 to 3.11)
Heart rate 1-min after the test (bpm)	172 ± 8*	167 ± 9	0.54 (-2.97 to 4.04)
Number of techniques in series A (rep)[a]	8 (8; 8)*	9 (8; 9)	0.59
Number of techniques in series B (rep)[a]	9 (8; 9)	9 (9; 9)	0.13
Number of techniques in series C (rep)[a]	8 (8; 9)	8 (8; 9)	0.00
Total number of techniques (rep)[a]	26 (24;26)	26 (25;26)	-0.39
Index SJFT (bpm/rep)	14.26 ± 10.52**	13.90 ± 1.11	0.60 (0.14 to 1.04)
Index JPFT (bpm/rep)	2.13 ± 0.69	2.42 ± 0.93	-0.37 (-0.71 to -0.03)
Rating of perceived exertion (a.u)[a]	8 (7; 8)*	8 (8; 9)	-0.52

Values are mean and standard deviation, unless marked otherwise; [a]Non-normal distribution variables: median values (lower and upper quartile); ES(95%CI) = effect size and 95% confidence interval * different from re-test (p < 0.05); ** different from re-test (p < 0.01)

Table 3. Measures of reliability and usefulness of physiological and performance variables of the Judo Physical Fitness Test.

Variable	ICC (95%CI)	TE (95%CI)	SWC (0.2, 0.6, and 1.2)	CV (%)	MDC
Resting blood lactate (mmol/L^{-1})	0.67 (0.12 to 0.91)	0.24 (0.17 to 0.44)	0.06, 0.18, 0.37	16.52	0.17
Blood lactate 3-min after the test (mmol/L^{-1})	0.91 (0.69 to 0.98)	0.68 (0.47 to 1.24)	0.38, 1.13, 2.26	5.12	1.05
Blood lactate 5-min after the test (mmol/L^{-1})	0.84 (0.47 to 0.96)	0.75 (0.51 to 1.36)	0.29, 0.88, 1.77	5.96	0.80
Peak blood lactate (mmol/L^{-1})	0.89 (0.62 to 0.97)	0.72 (0.49 to 1.31)	0.35, 1.06, 2.13	5.41	0.97
Heart rate after the test (bpm)	0.91 (0.69 to 0.98)	2.13 (1.47 to 3.90)	1.18, 3.55, 7.09	1.17	3.27
Heart rate 1-min after the test (bpm)	0.87 (0.57 to 0.97)	3.40 (2.34 to 6.21)	1.54, 4.63, 9.26	2.03	4.27
Number of techniques in series A (rep)[a]	0.59 (-0.02 to 0.88)	0.34 (0.23 to 0.64)	0.07, 0.22, 0.44	4.05	0.19
Number of techniques in series B (rep)[a]	0.61 (0.01 to 0.89)	0.40 (0.28 to 0.73)	0.09, 0.27, 0.54	4.65	0.25
Number of techniques in series C (rep)[a]	0.85 (0.52 to 0.96)	0.33 (0.23 to 0.61)	0.14, 0.42, 0.84	4.28	0.39
Total number of techniques (rep)[a]	0.85 (0.51 to 0.96)	0.68 (0.47 to 1.25)	0.29, 0.86, 1.71	2.67	0.80
Index SJFT (bpm/rep)	0.90 (0.66 to 0.97)	0.39 (0.27 to 0.70)	0.20, 0.61, 1.21	2.71	0.55
Index JPFT (bpm/rep)	0.73 (0.23 to 0.93)	0.47 (0.32 to 0.85)	0.13, 0.40, 0.81	19.93	0.36
Rating of perceived exertion (a.u)[a]	0.41 (-0.25 to 0.81)	0.48 (0.33 to 0.87)	0.07, 0.22, 0.44	6.65	0.19

[a]Non-normal distribution variables: median values (lower and upper quartile); ICC (95%CI) = intraclass correlation coefficient and 95% confidence interval; TE = typical error and 95% confidence interval; SWC = smallest worthwhile change; CV(%) = typical error expressed as coefficient of variation; MDC = minimal detectable change

Table 4. Significant correlations between the Judo Physical Fitness Test and the four performance tests and Likert scale for the effort similarity.

		r	R^2	p
SJFT	**JPFT**			
Blood lactate 3-min after the test (mmol/L)	Blood lactate 3-min after the test (mmol/L)	0.66	0.44	0.04
Heart rate after the test (bpm)	Heart rate after the test (bpm)	0.87	0.75	0.00
Index (bpm/rep)	Index SJFT (bpm/rep)	0.72	0.51	0.02
SJM	**JPFT**			
Heart rate after the test (bpm)	Heart rate after the test (bpm)	0.81	0.66	0.00
Heart rate 1-min after the test (bpm)	Heart rate 1-min after the test (bpm)	0.79	0.62	0.01
Heart rate after the test (bpm)	Index SJFT (bpm/rep)	0.64	0.40	0.05
WAnT	**JPFT**			
Time to reach peak power (s)	Number of techniques in series A (rep)	0.71	0.50	0.02
IET	**JPFT**			
Heart rate after the test (bpm)	Heart rate after the test (bpm)	0.77	0.59	0.01
Likert scale	**JPFT**			
Official match	Blood lactate 5-min after the test (mmol/L)	0.84	0.71	0.00
Official match	Peak blood lactate (mmol/L)	0.72	0.51	0.02
Simulated match	Peak blood lactate (mmol/L)	0.71	0.50	0.02
Simulated match	Rating of perceived exertion (a.u)	0.68	0.46	0.03

r = Pearson product moment correlation coefficient; R^2 = coefficient of determination; p – value; JPFT = judo physical fitness test; SJFT = special judo fitness test; SM = simulated match; WAnT = Wingate test; IET = incremental exercise test

perfect reliability; (c) TE was higher than SWC for all variables when the small difference (i.e., 0.2 multiplied by between-participants SD) was considered, medium variations could be properly detected for sum of repetitions in the three sets, [La] 3-min, 5-min, and peak after the test, HR after and 1-min after the test, and SJFT index, and only large variations could be detected for all other variables. These findings suggest that using JPFT as a performance outcome will only allow for the detection of medium or large changes when investigating the effect of a given intervention on judo performance; (d) large and very large correlations were observed between [La] and HR in the JPFT and those in the SJFT and SJM. Moreover, the similarity of effort during match simulation and an official match was correlated with [La] and HR responses to the JPFT.

As there were decreases in [La] and HR post-JPFT and increases in the number of throws in the first set and RPE in the re-test compared to pre-test, probably an additional repetition should be necessary to stabilize the results. However, it is important to emphasize that the reliability indexes for most of the variables assessed in the JPFT were large to nearly perfect, suggesting the results are reliable and can be used in the judo athlete's assessment. This values are similar to those reported in the literature for the SJFT [Franchini *et al.* 2009; Sterkowicz-Przybicien *et al.* 2017], which is the most judo-specific test used.

One important aspect to be considered when applying the test proposed is its usefulness, as medium variations can be properly detected for the sum of technique repetitions, [La] and HR responses, while only large variation can be detected for the other variables. Thus, coaches and sport scientists should use JPFT test only when medium and large variations are expected from specific interventions (e.g. training protocols, ergogenic aids supplementation, recovery procedures, etc.). Small variations cannot be properly identified, and caution is needed in such cases. It is important to emphasize, however, that other judo-specific tests lack this important information [Chaabene *et al.* 2018], and a comparison between the test presented here and other judo-specific tests concerning this aspect is difficult to conduct. Furthermore, future studies should be developed to check if more test repetitions or the execution of this test by other groups of judo athletes can improve this scenario. Another important feature of the JPFT was its large and very large relationship with both SJM and SJFT responses, concerning physiological responses (i.e., [La] and HR). This indicates that this test induced a similar physiological demand as those typically observed during randori (match simulation) and the most used judo-specific test [Franchini *et al.* 2009; Franchini *et al.* 2011]. Additionally, judo athletes indicated that they perceived the effort during the new test as similar to that faced during both simulated and official matches, confirming that its physiological demand is likely similar to that from a judo contest. Hence, this test can be used to monitor physiological adaptation to the judo-specific effort.

The evaluation of athlete's physical fitness is essential in the training process because it represents the basis for successful periodization, i.e. planning and programming of the training process. It is well known that competitive performance in judo determines a whole range of features

and abilities, as well as technical-tactical preparedness of judo athletes. Therefore, we have constructed a test that by its characteristics greatly simulates the physical demand of a judo match. Although this is an initial investigation on young athletes, the obtained results have shown good statistical reliability and validity of the new test. Moreover, the JPFT is performed on the tatami, and it does not require expensive equipment.

Conclusions

In summary, our results indicated that the JPFT performance and physiological responses did not totally stabilize with only two repetition, but most of the variables were highly reliable. Medium and large changes can be properly assessed for most of the test variables, indicating a moderate usefulness. Finally, the physiological responses and perceived effort in this test were correlated with those observed in the SJFT and in simulated and official matches, suggesting it can be used to monitor the physiological adaptation and effort perception to judo-specific training. Judo coaches can replicate JPFT easily to establish information on the current athletes' performance and physiological responses in a judo-specific task and analyse the changes occurring due to specific interventions: training protocols, ergogenic aids supplementation, recovery procedures, etc.

Acknowledgements

The authors wish to thank all participants for their enthusiastic participation in this investigation. The last author is supported by a FAPESP grant (2017/08167-2) and a CNPq grant (302242/2014-7).

Disclosure statement

The authors report no conflict of interest.

References

1. Agostinho M.F., Junior J.A.O., Stankovic N., Escobar-Molina R., Franchini E. (2018), *Comparison of special judo fitness test and dynamic and isometric judo chin-up tests' performance and classificatory tables' development for cadet and junior athletes*, "Journal of Exercise Rehabilitation", vol. 14, no. 2, pp. 244–252; https://doi.org/10.12965/jer.1836020.010.
2. Almansba R., Sterkowicz S., Sterkowicz-Przybicien K., Comtois A.S. (2012), *Reliability of the Uchikomi Fitness Test: a pilot study*, "Science & Sports", vol. *27,* no. 2, pp. 115–118; https://doi.org/10.1016/J.SCISPO.2011.09.001.
3. Bangsbo J., Mohr M., Poulsen A., Perez-Gomez J., Krustrup P. (2006), *Training and testing the elite athlete*, "Journal of Exercise Science and Fitness", vol. 4, no. 1, pp. 1–14.
4. Beaver W.L., Wasserman K., Whipp B.J. (1986), *A new method for detecting anaerobic threshold by gas exchange*, "Journal of Applied Physiology", vol. 60, no. 6, pp. 2020–2027; https://doi.org/10.1152/jappl.1986.60.6.2020.
5. Bromley S.J., Drew M.K., McIntosh A., Talpey S. (2018), *Rating of perceived exertion is a stable and appropriate measure of workload in judo*, "Journal of Science and Medicine in Sport"; https://doi.org/10.1016/j.jsams.2018.02.013.
6. Castarlenas J., Planas A. (1997), *Estudio de la estructura temporal del combate de judo,* "Apunts. Education Física y Deportes. Educación Física y Deportes", vol. 1, no. 47, pp. 81–87 [in Spanish].
7. Chaabene H., Negra Y., Bouguezzi R., Capranica L., Franchini E., Prieske O., Granacher U. (2018), *Tests for the he assessment of sport-specific performance in Olympic combat sports: a systematic review with practical recommendations*, "Frontiers in Physiology"; https://doi.org/10.3389/fphys.2018.00386.
8. Cohen J. (1988), *Statistical power analysis for the behavioral sciences*, New York, NY, Routledge Academic.
9. Detanico D., Dal Pupo J., Franchini E., Giovana dos Santos S. (2012), *Relationship of aerobic and neuromuscular indexes with specific actions in judo*, "Science & Sports", vol. 27, no. 1, pp. 16–22; https://doi.org/10.1016/J.SCISPO.2011.01.010.
10. Drust B., Waterhouse J., Atkinson G., Edwards B., Reilly T. (2005), *Circadian rhythms in sports performance--an update*, "Chronobiology International", vol. 22, no. 1, pp. 21–44.
11. Franchini E., Sterkowicz S., Szmatlan-Gabrys U., Gabrys T., Garnys M. (2011), *Energy system contributions to the Special Judo Fitness Test*, "International Journal of Sports Physiology and Performance", vol. 6, no. 3, pp. 334–343.
12. Franchini E., Takito M., Dal M., Kiss M., Sterkowicz S. (2005), *Physical fitness and anthropometric differences between elite and non-elite judo players*, "Biology of Sport", vol. 22, pp. 315–328.
13. Franchini E., Vecchiio F.B., Sterkowicz S. (2009), *A Special Judo Fitness Test classificatory table*, "Archives of Budo", vol. 5, pp. 127–129.
14. Gao S., Zhai Y., Yang L., Zhang H., Gao Y. (2018), *Preferred temperature with standing and treadmill workstations*, "Building and Environment", vol. 138, pp. 63–73; https://doi.org/10.1016/J.BUILDENV.2018.04.027.
15. Hopkins W.G. (2000), *Measures of reliability in sports medicine and science*, "Sports Medicine", vol. 30, no. 1, pp. 1–15.
16. Hopkins W.G. (2018), *A new view of statistics*. Retrieved from Sportsci.org
17. Hopkins W.G., Marshal S.W., Batterham A.M., Hanin J. (2009), *Progressive statistics for studies in sports medicine and exercise science*, "Medicine & Science in Sports & Exercise", vol. 41, no. 1, pp. 3–13; https://doi.org/10.1249/MSS.0b013e31818cb278.
18. Hopkins W.G., Schabort E.J., Hawley J.A. (2001), *Reliability of power in physical performance tests*, "Sports Medicine", vol. 31, no. 3, pp. 211–234.

19. Howley E.T., Bassett D.R., Welch H G. (1995), *Criteria for maximal oxygen uptake: review and commentary*, "Medicine and Science in Sports and Exercise", vol. 27, no. 9, pp. 1292–1301.
20. Julio U.F., Panissa V.L.G., Esteves J.V., Cury R.L., Agostinho M.F., Franchini E. (2017), *Energy-system contributions to simulated judo matches*, "International Journal of Sports Physiology and Performance", vol. 12, no. 5, pp. 676–683; https://doi.org/10.1123/ijspp.2015-0750.
21. Kyle U.G., Bosaeus I., De Lorenzo A.D., Deurenberg P., Elia M., Manuel Gomez J., Lilienthal Heitmann B., Kent-Smith L., Melchior J.C., Pirlich M., Scharfetter H., M W J Schols A., Pichard C., ESPEN. (2004), *Bioelectrical impedance analysis—part II: utilization in clinical practice*, "Clinical Nutrition", vol. 23, no. 6, pp. 1430–1453; https://doi.org/10.1016/j.clnu.2004.09.012.
22. Lidor R., Melnik Y., Bilkevitz A., Falk B. (2006), *The ten-station judo ability test: a test of physical and skill components*, "Strength and Conditioning Journal", vol. 28, no. 2, pp. 18–20.
23. Marcon G., Franchini E., Jardim J.R., Barros Neto T.L. (2010), *Structural analysis of action and time in sports: judo*, "Journal of Quantitative Analysis in Sports", vol. *6, no.* 4; https://doi.org/10.2202/1559-0410.1226.
24. Meckel Y., Machnai O., Eliakim A. (2009), *Relationship among repeated sprint tests, aerobic fitness, and anaerobic fitness in elite adolescent soccer players*, "Journal of Strength and Conditioning Research", vol. 23, no. 1, pp. 163–169; https://doi.org/10.1519/JSC.0b013e31818b9651.
25. Miarka B., Cury R., Julianetti R., Battazza R., Julio U.F., Calmet M., Franchini E. (2014), *A comparison of time-motion and technical–tactical variables between age groups of female judo matches*, "Journal of Sports Sciences", vol. 32, no. 16, pp. 1529–1538; https://doi.org/10.1080/02640414.2014.903335.
26. Miarka B., Panissa V.L.G., Julio U.F., Del Vecchio F.B., Calmet M., Franchini E. (2012), *A comparison of time-motion performance between age groups in judo matches*, "Journal of Sports Sciences" vol. 30, no. 9, pp. 899–905; https://doi.org/10.1080/02640414.2012.679675.
27. Neovius M., Hemmingsson E., Freyschuss B., Udden J. (2006), *Bioelectrical impedance underestimates total and truncal fatness in abdominally obese women*, "Obesity", vol. 14, no. 10, pp. 1731–1738; https://doi.org/10.1038/oby.2006.199.
28. Padulo J., Powell D.W., Ardigo L.P., Viggiano D. (2015), *Modifications in activation of lower limb muscles as a function of initial foot position in cycling*, "Journal of Electromyography and Kinesiology", vol. 25, no. 4, pp. 648–652; https://doi.org/10.1016/j.jelekin.2015.03.005.
29. Santos L., Gonzalez V., Iscar M., Brime J.I., Fernandez-Rio J., Egocheaga J., Rodriguez B., Montoliu M. a. (2010), *A new individual and specific test to determine the aerobic-anaerobic transition zone (Santos Test) in competitive judokas*, "Journal of Strength and Conditioning Research", vol. 24, no. 9, pp. 2419–2428; https://doi.org/10.1519/JSC.0b013e3181e34774.
30. Santos L., Gonzalez V., Iscar M., Brime J.I., Fernandez-Río J., Rodríguez B., Montoliu M. a. (2011), *Retesting the validity of a specific field test for judo training*, "Journal of Human Kinetics", vol. 29, pp. 141–150; https://doi.org/10.2478/v10078-011-0048-3.
31. Sattler T., Sekulic D., Hadzic V., Uljevic O., Dervisevic E. (2012), *Vertical jumping tests in volleyball*, "Journal of Strength and Conditioning Research", vol. 26, no. 6, pp. 1532–1538; https://doi.org/10.1519/JSC.0b013e318234e838.
32. Sbriccoli P., Bazzucchi I., Di Mario A., Marzattinocci G., Felici F. (2007), *Assessment of maximal cardiorespiratory performance and muscle power in the Italian Olympic judoka*, "Journal of Strength and Conditioning Research", vol. 21, no. 3, pp. 738–744; https://doi.org/10.1519/R-20245.1.
33. Sterkowicz-Przybicien K., Fukuda D., Franchini E., Sterkowicz S. (2017), *Special Judo Fitness Test: results and applications* [in:] P. Drid [ed.], *Science and Medicine in Combat Sports*, New York, Nova Publishers, pp. 145–173.
34. Sterkowicz-Przybicien K.L., Fukuda D.H. (2014), *Establishing normative data for the Special Judo Fitness Test in female athletes using systematic review and meta-analysis*, "Journal of Strength and Conditioning Research", vol. 28, no. 12, pp. 3585–3593; https://doi.org/10.1519/JSC.0000000000000561.
35. Sterkowicz S. (1995), *W Poszukiwaniu nowego testu specjalnej sprawnosci ruchowej w judo,* "Trening", vol. 3, pp. 46–60 [in Polish].
36. Tavra M., Franchini E., Krstulovic S. (2016), *Discriminant and factorial validity of judo-specific tests in female athletes*, "Archives of Budo", vol. 12, pp. 93–99.
37. Tomaras E.K., MacIntosh B.R. (2011), *Less is more: standard warm-up causes fatigue and less warm-up permits greater cycling power output*, "Journal of Applied Physiology", vol. 111, no. 1, pp. 228–235; https://doi.org/10.1152/japplphysiol.00253.2011.
38. Uljevic O., Spasic M., Sekulic D. (2013), *Sport-specific motor fitness tests in water polo: reliability, validity and playing position differences*, "Journal of Sports Science & Medicine" vol. 12, no. 4, pp. 646–654.

Wiarygodność i ważność nowego Testu Sprawności Fizycznej w Judo

Słowa kluczowe: sporty walki, testy terenowe, wydolność fizjologiczna, zdolności motoryczne, ocena

Abstrakt

Tło. Ocena zawodników jest kluczowym elementem podczas procesu szkolenia. Chociaż istnieją pewne testy przeznaczone specjalne dla judo, to żaden z nich nie przedstawia wpływu głównych działań judo (chwytanie, rzucanie itp.) na jego strukturę. Problem i cel. Ocena wiarygodności, przydatności i ważności nowego testu sprawności fizycznej w judo (JPFT), który przedst-

awia techniki chwytania, rzucania i inne podstawowe działania.
Metody. 10 mężczyzn, zawodników judo (16,5 ± 0,5 roku, wzrost = 181,0 ± 7,7 cm, masa ciała = 78,3 ± 11,5 kg) wykonało testy JPFT dwa razy w oddstępie 48 godzin. Ważność testu została ustalona poprzez zbadanie związku między testami: JPFT a testem Wingate'a, testem specjalnym w Judo (SJFT), symulowaną walką judo (SJM) i przyrostowym testem wysiłkowym (IET).
Wyniki. Wszystkie wartości ICC były statystycznie istotne, z wyjątkiem kilku technik w serii A i ocenie postrzeganego wysiłku (RPE) z dwiema zmiennymi cechującymi się dużą wiarygodnością (spoczynkowy poziom mleczanu we krwi, [La], liczba technik w serii B), sześć bardzo dużych poziomów niezawodności ([La] 5 min po teście, szczytowy punkt [La], częstość akcji serca, HR, 1 minuta po teście, liczba technik w serii C, całkowita liczba technik, indeks JPFT) i trzy prawie doskonałe poziomy niezawodności ([La] 3 min po teście, HR po teście, indeks SJFT). Obserwowano duże i bardzo duże korelacje między [La] i HR w teście JPFT oraz w SJFT i SJM. Podobieństwo wysiłku podczas oficjalnej walki było skorelowane z [La] 5 min po teście (r = 0,84) i momencie szczytowym [La] (r = 0,71) i RPE (r = 0,68) z JPFT.
Wnioski. Test JPFT ma podobne wymagania fizjologiczne, jak te typowo obserwowane podczas symulacji walki i innych testów przeznaczonych specjalnie dla judo. Dlatego test ten można wykorzystać do monitorowania fizjologicznej adaptacji u zawodników judo.