Original article

Maximal lactate steady state in Judo

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Summary

***Background*: the purpose of this study was to verify the validity of respiratory compensation threshold (RCT) measured during a new single judo specific incremental test (JSIT) for aerobic demand evaluation. *Methods*: to test the validity of the new test, the JSIT was compared with Maximal Lactate Steady State (MLSS), which is the gold standard procedure for aerobic demand measuring. Eight well-trained male competitive judo players (24.3 ± 7.9 years; height of 169.3 ± 6.7cm; fat mass of 12.7 ± 3.9%) performed a maximal incremental specific test for judo to assess the RCT and performed on 30-minute MLSS test, where both tests were performed mimicking the UchiKomi drills. *Results*: the intensity at RCT measured on JSIT was not significantly different compared to MLSS (p=0.40). In addition, it was observed high and significant correlation between MLSS and RCT (r=0.90, p=0.002), as well as a high agreement. *Conclusions*: RCT measured during JSIT is a valid procedure to measure the aerobic demand, respecting the ecological validity of Judo.**

KEY WORDS: ergometer, domain intensity, field test, metabolic demand, second ventilatory threshold.

Introduction

Numberless research articles in sports sciences are aimed to validate evaluation tests of physical capacity that are specific for the reality of the sportive activities[1-5], thus stimulating and monitoring the training effectiveness[6]. Within this perspective, there are few specific tests for judo[7].

The fact that judo is a complex modality with several body movements and metabolic interactions, makes it difficult to assess the aerobic performance specifically. The traditional incremental test on treadmill or cycle-ergometer exercises do not mimic the specific muscular demand and movement patterns performed during the judo match. Specific evaluation procedure and training regarding aerobic demand could improve performance in judo[8]. Furthermore, activities lasting more than 3 minutes are strongly influenced by aerobic metabolism[9] and considering the overall judo match, the energy aerobic pathway has a relevant role in maintaining the high-intensity of efforts during the fight and for allowing for fast recovery after each effort periods, being the main energy system during the match[10].

Until at the moment there is a lack in the science of validity specific tests to assess the aerobic demand in judo athletes. Moreover, the specific test for judo in the current literature cannot be used for intensity training prescription. Our hypothesis is the following: a) there will be no statistical difference between RCT-related intensity and MLSS; b) there will be high agreement between the methods aimed at testing judo. Whether these hypotheses are confirmed, its open a new way for specific training because athlete could train with a specific and appropriate load, without the presence of another athlete (required for traditional UchiKomi). Therefore, the purpose of the present study was to verify the validity of respiratory compensation threshold (RCT) measured during a new single judo specific incremental test (JSIT) (i.e., performed mimicking the UchiKomi drills) for aerobic demand evaluation. Facing this purpose, the RCT measured on JSIT was compared with maximal lactate steady state (i.e., gold standard procedure for aerobic demand evaluating) that represent the upper limit of equilibrium between lactate production and removal[11]. The advantage to using JSIT is because this procedure needs only one single test, while MLSS requires 2 to 5 days.

Methods

Subjects

Eight well-trained male judo athletes with a mean age of 24.2 ± 6.4 years old, mean height of 168.2 ± 7.0-cm, and mean body mass of 65.4 ± 13.2-kg participated voluntarily in this study. Four judo athletes competed at national-level tournaments, whereas four others play state competitions. The mean time spent on training was 10.5 ± 0.4 hours a week. All participants of this investigation were textually and verbally informed about the possible intrinsic risks and benefits of the tests, signing a free informed consent. The study was approved by the research ethics committee of the Federal University of São Carlos, Brazil (Human Research Ethics Committee protocol number 257/2006) which followed the ethical standard of the Muscle, Ligament and Tendons Journal[12].

Study protocol

All the subjects performed a specific incremental test (JSIT) and MLSS mimicking the *Uchikomi* using a cable crossover machine. The JSIT was performed until exhaustion. Next, constant workload was performed at intensities around Respiratory Compensation Threshold (RCT) for determination of Maximal Lactate Steady State (MLSS). The tests were conducted on the same period of the day, with a variation of 2 hours. The interval between test was 72 hours.
Warm-up exercises consisting of specific judo movements were performed for 5 minutes prior to each test. To minimize the learning effect, the judo athletes attended 5-minute *UchiKomi* sessions using a cable crossover machine for 4 non consecutive days[13]. The pace of *Uchikomi* was controlled through loud signs emitted by a metrometer (*D'Accord Metronome, freeware*).

Experimental procedures

Specific actions during graded exercise and maximal lactate steady state in judo test

Both tests were developed so that *uchikomi* would be applied in association with *ippon-seoi-nague* technique using a cable crossover machine, with the adaptation of the kimono sleeves onto the equipment. The validity and reliability of UchiKomi use for anaerobic threshold determination has been demonstrated previously[14]. Initial load for JSIT was 1.9-kg, increasing 1.2-kg every 3 minutes[15]. For MLSS test the load was around RCT determined during JSIT. *UchiKomi* movements had a frequency of one *UchiKomi* every 3 seconds[16]. The test was finished when the subject stopped the movement voluntarily due to exhaustion, when the pre-determined frequency was not kept during 3 consecutive *Uchikomi*, or when U*chikomi* was performed out of the technical pattern. At the end of each stage, there was a 30-second interval for load increment during JSIT, or blood collection during MLSS test.

Graded exercise test for respiratory compensation threshold determination in Judo

Measurements of VO_2, VCO_2 and ventilation were carried out throughout each test using a telemetry system (K4b^2, Cosmed, Rome, Italy). Expired gases were measured breath-by-breath and the results were averaged every 15 seconds. Before each test, the system for O_2 analysis was calibrated using ambient air and a gas of known O_2 and CO_2 concentration according to the manufacturer's instructions (K4 b^2 instruction manual) and subjects remain standing during 5 minutes for data acquisition and normalization. The turbine flowmeter of the K4 b^2 was calibrated using a 3-L syringe.
The RCT was determined by means of three ventilatory parameters: 1) second loss in ventilatory linearity; 2) increase of representative curve corresponding to ventilatory equivalent of CO_2 (VE/VCO_2); 3) decrease in the fraction of expired CO_2 ($\%FeCO_2$)[17]. Two experienced scientists evaluated each graph, and in the case of discrepancies, the mean of the identified points was used.

Maximal lactate steady state

A constant-load test was carried out during 30 minutes[11]. A minimum of 48 hours and a maximum of 96 hours of intervals were allowed after JSIT as well as between the tests for MLSS determination. This test was performed at an intensity of 1.2-kg below the RCT, at an intensity corresponding to RCT, and 1.2-kg above the RCT intensity. MLSS was considered as being the greatest intensity in which blood lactate concentration did not increase more than 1-mmol. L^{-1} between 10 and 30 minutes[11].

Blood collection and analysis

Blood sample collection was carried out by puncture with disposable lancet perforating ear lobe. Heparised capillaries were used for containing 25-μL of arterial blood, which were then put in Eppendorf tubes containing 50-μL of 1% sodium fluoride. All samples were stored in the freezer for adequate conservation and further analysis. Blood lactate concentrations were measured by an electro-enzymatic lactate analyzer (Model YSI 1500 Sports - Yellow Springs Instruments, Ohio, USA). The values of lactate were expressed in mmol. L^{-1}.

Statistical analysis

Data are presented as mean ±SD. The difference between the intensity related to RCT and MLSS was analyzed with a paired *t*-test. It was also applied the

Shapiro-Wilk test for assessing the normality data. The relationships between RCT and MLSS were determined by the Pearson's correlation coefficient. Coefficient of variation was calculated as follows: CV=(SD/mean)×100. The significant level was set at $p \leq 0.05$. Moreover, error and limits of agreement between methods[11] were calculated, considering MLSS as gold standard. The minimal sample power required for this study was eleven.

Results

The load, percentage of maximum, blood lactate concentration, heart rate and VO_2 at RCT and MLSS and their coefficient of variations were presented in Table 1. *Uchikomi* absolute and percentage load at RCT was not significantly different compared to MLSS ($p > 0.05$). These values were significantly correlate ($r=0.90$; $R^2=0.80$; $p=0.002$) and showed high agreement between MLSS and RCT (Fig. 1). Low bias and relatively narrow limits of agreement [Bias (±95% confidence interval)] for MLSS and RCT [-0.3 (1.04) kg] was observed[18]. The coefficient of variations was demonstrated in Table 1.

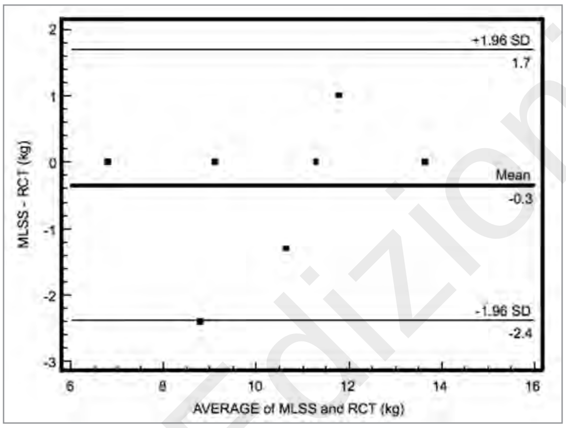

Figure 1. Bland-Altman plots showing the bias and limits of agreement in comparison of MLSS and RCT. The solid horizontal line represents the bias between the two measures. The dashed lines represent the 95% limits of agreement between the two variables.

Discussion

The main finding was that RCT may predict the MLSS in a specific judo test by means of the non-invasive methodology. Although considered an effective test, the MLSS identification needs two to five constant work loads exercise tests of up 20 to 30-min duration. Therefore, a single and noninvasive test for MLSS prediction becomes interesting for athlete evaluation and training prescription.

The traditional laboratory tests using a treadmill or cycle-ergometer for determination of sub-maximum (RCT) parameters seem not to be able to discriminate elite athletes from non-elite ones[19]. In an attempt to fulfill this gap, the test being suggested here opens a good perspective for evaluating the judo athlete's aerobic capacity. Comparison of the individual load test results between RCT and MLSS can be observed in Figure 1. Four subjects had the same intensity for either RCT or MLSS, with low estimation error (bias) indicating that such parameters are interchangeable. Lactate concentration at RCT and MLSS were similar to reported in other studies with different sports and methods[20, 21]. The VO_2 max determined by incremental test was similar to reported in literature with specific and non-specific methods[14, 22, 23]. Therefore, JIST will serve as an intensity parameter for training and evaluation purposes.

The percentage values for RCT and MLSS at JIST, in relation to peak load, were found to be similar to that reported in the literature on tests based on a treadmill and cycle-ergometer[20, 24, 25]. It was observed good correlation and agreement between MLSS and RCT. Because this similarity found we suggest that RCT can be used instead of MLSS to determine the athlete's evolution and specific intensity of training for judo.

The development of a specific procedure for judo is complex because several variables are needed for a good performance during the combat[26]. In the present study, we have used only "*ippon-seoi-nague*". It should be emphasized that this modality also involves another type of throwing movements (e.g. *uchi-mata, o-soto-gari*, among others) that are important and largely employed for sports performance. However, *ippon-seoi-nague* is a technique similar to *morote-seoi-nague,* that depends more the aerobic energy yield during its execution[27]. These facts, largely employ-

Table 1. The absolute and percentage of peak load for RCT and MLSS.

	Absolute Load (Kg)	Percentual of Peak load (%)	Heart Rate (bpm)	[Lac^-] ($mmol.L^{-1}$)	VO_2 ($ml.kg^{-1}. min^{-1}$)
RCT	10.3 ± 1.9 (8.6 – 12.0)	82.6 ± 2.8 (80.1 – 5.1)	169.9 ± 3.5 (160.6 – 77.1)	2.9 ± 0.8 (2.0 – 3.6)	38.4 ± 4.9 (34.0 – 2.8)
C.V.	18.4	3.4	2.1	27.6	12.8
MLSS	10.0 ± 2.3 (8.0 – 11.9)	79.9 ± 8.5 (72.3 – 7.4)	166.6 ± 6.1 (152.1 – 81.0)	3.1 ± 0.8 (2.4 – 3.9)	
C.V.	23.0	10.6	3.7	25.8	-
P-value	0.388	0.378	0.751	0.608	-
Effect size	0.14	0.48	0.69	0.31	-

ment and high aerobic demand for *ippon-seoi-nague* techniques, strengthens the method proposed here.

One of the limitations during the judo fights is the handgrip fatigue[28]. Improving specifically the handgrip endurance can contribute to optimal performance[28]. These muscles represent a crucial factor that limits the tests being conducted, according to a report by the subjects. A good simulation was observed in one of the limiting factors that occur during a real combat. The stressful components of competition may temporarily impair an athlete's performance during a subsequent combat. So, a specific evaluation procedure and training regarding endurance capacity could improve performance in judo between and within combats.

Due to predominantly aerobic metabolism during judo match[10], it is clearly the need for determining the intensity of exercise to adequately prescript the specific aerobic training. It is recommended that physical exercises during judo training use upper and lower limbs jointly with an intensity associated with lactate threshold[29, 30]. Therefore, the JIST can contribute to making the kinetic chain movement to be closer to the reality. This specificity of evaluation and training could induce to a better performance and adaptation of the judo athlete in keeping intense physical efforts without becoming exhausted[29, 30], thus yielding less lactate concentration and faster re-synthesis of phosphate creatine[8].

Here we used the second ventilatory threshold for estimation of MLSS. For judo, two studies were aimed at determining the intensity associated with MLSS by using the minimum lactate concept[16] and individual anaerobic threshold[14]. The lactate minimum test has been found to be a good way for predicting such intensity[31]. Both methods represent the upper limit of effort intensity in which lactate appearance is in dynamic balance with its removal from the blood[11, 20]. It has been suggested that training at MLSS intensity is adequate approach to improve the aerobic power and capacity[32].

Possibly the limitation of this study is the number of subjects. The minimal sample power required for this study was eleven. However, all data were considered with normal distribution. Other procedures like test-retest, verify if JSIT is able to discriminate level of performance in judo players. The strengths of this study are a novel strategy to determine in a specific way the aerobic capacity for judo athletes, and the methodology reported here could be applied as judo evaluation and load training prescription.

In conclusion, JSIT was cross-validated to specifically estimate MLSS for sporting purposes. Therefore, the JSIT can be used to evaluate the aerobic conditioning of judo practitioners and for prescribing adequate intensity training.

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