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Analysis of Lactate, Heart Rate and Rating of Perceived Exertion Responses in Randori, Competition and Specific Evaluation of Judo

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Key words: *judo*, internal load, blood lactate, heart rate, rating of perceived exertion

Abstract

Background. Blood lactate [La-], heart rate (HR) and rating of perceived exertion (RPE) have been used to quantify the intensity of effort in judo.

Problem and Aim. The relationship among the variables, [La-], HR and RPE after the first fight in the official competition (1-OC), one Randori (RAN), and the Special Judo Fitness Test (SJFT) have not been studied together. Therefore, the present study aimed to verify the correlations among [La-], HR and RPE in the RAN, 1-OC and SJFT, and the change of these variables in the three conditions.

Methods. The sample consisted of 16 state and national level judokas, 8 men and 8 women, aged: 18 ± 0.9. Anthropometric assessment, SJFT and RAN were conducted in the first week and in the second one, judokas participated in the competition. HR, RPE and [La-] were collected in the SJFT and RAN, while in the 1-OC, only RPE and [La-] were collected.

Results. [La-] differed amongst the three situations, with higher values in the SJFT followed by the 1-OC and RAN. In relation to RPE, SJFT also presented higher values in relation to the 1-OC. There was a high correlation between HRmed and RPE in the SJFT and between HRmax and [La-] in the RAN.

Conclusions. For the category studied, [La-] best discriminated the specific actions of judo, the HR did not seem to be a good indicator of the intensity of the specific activities of judo. More studies with RPE in training sessions and complete competitions must be held to add new information to the results found.

Introduction

Judo is a combat sport with several technical actions that are influenced by the opponent's reactions and movements, leading to a relationship of effort: pause that varies between 18-30s:7-14s. Such a relationship is influenced by the competitive level, technical-tactic variation, styles, and strategies, requiring a specific analysis of physiological demands during training and competitions [Franchini, Artioli, Brito 2013; Miarka *et al*. 2016]. Considering such complexity and judokas' preparation demands, control and evaluation are essential for specific training and competitions.

Among the specific tests for judo, the most widely used test is certainly the Special Judo Fitness Test (SJFT). The SJTF assesses the specific physical fitness of the judo athletes and consists of 3 sets of maximum effort of 15s, 30s and 30s, with 10s intervals between each of them [Sterkowicz 1996]. It also requires a metabolic demand which is equivalent to that of a judo competition [Franchini *et al*. 1998; Sterkowicz, Franchini, Heinisch 2005; Casals *et al*. 2016]. The SJFT has been used to discriminate between judo medalists and non-medalists in high-level competitions [Sterkowicz, Zuchowickz, Kubica 1998; Sterkowicz, Franchini, Heinisch 2005] and based on the test result a classification has been proposed to discriminate the specific physical fitness for judo [Franchini, Del Vecchio, Sterkowicz 2009].

Although the specific tests can discriminate the level of physical fitness of judokas and present similar metabolic demand to the competition, Randori (RAN) is a fight simulation between two judokas that can be used as a fight simulation specific assessment for it entails physical, technical and tactical demands as in a competition. RAN also presents situations of unpredictability [Miarka *et al*. 2012] and a physiological demand similar to the competition [Bonitch-Dominguez *et al*. 2010; Obminski *et al*. 2010]. Both the RAN and the competitive fight present a high demand for the glycolytic pathway, reaching blood lactate concentrations ([La^-]) between 8-14 $mmol.l^{-1}$ [Franchini *et al*. 2004; Bonitch-Dominguez *et al*. 2010; Obminski *et al*. 2010; Torres-luque *et al*. 2016]. For this reason, [La^-] has been proposed as the most important indicator to quantify the level of effort in judo combats [Obminski *et al*. 2010; Simao *et al*. 2016].

In addition to [La^-], heart rate (HR) and rating of perceived exertion (RPE) have been used to quantify the intensity of effort in judo, which represent the internal load, characterized by a response to proposed stimulus [Impellizzeri *et al*. 2004]. HR has been investigated as a possible parameter for controlling the training load in judo [Houvenaeghel *et al*. 2005; Branco *et al*. 2013], although the use of HR monitors during competitions is difficult because the rules do not allow attached instruments to the body. RPE has also been used to control the training load in judo [Agostinho *et al*. 2015] and is considered a good indicator of internal training load for other sports [Impellizzeri, Marcora, Coutts 2019]. However, the analysis of the relationship between the load planned by the judo coach (external load) and that experienced by the judo athletes (internal load) showed significant differences, with the athletes reporting a higher RPE than that idealized by the coach [Viveiros *et al*. 2011].

Some studies have verified the relationship between RPE and the physiological indicators of internal load in judo, [La^-] and HR. The results in competition and RAN are contradictory. In an official competition, Serrano *et al*. [2001] observed a high correlation between RPE and [La^-] after the last fight of the competition. Moderate correlations between RPE and HR and low association between RPE and [La^-] were observed after several RANs in the same training session [Branco et al. 2013]. However, the results differed when the RAN assessment was carried out after the first fight, showing a high correlation between RPE and HR after the first RAN fight [Simao et al. 2016]. Studies in official competitions are difficult to carry out because access to judokas is not allowed. In addition, the relationship among the internal load variables, [La^-], HR and RPE after the first fight in official competition (1-OC), one RAN, and the SJFT have not been studied together so far. Considering this gap in the literature, the present study aimed to verify the correlations among [La^-], HR and RPE in the RAN, 1-OC and performance in the SJFT, and to compare the change of these variables in the three conditions.

Methods

Sample

The sample consisted of 16 state and national level judokas from the SESI-Bauru-SP team, 8 men and 8 women, aged 17 to 20 years (18 ± 0.9), who trained 3h/day, 5 times/week. The present research was approved by the University Research Ethics Committee (CAAE: 53686516.7.0000.5398), in accordance with Brazilian current legislation. After the presentation of the study and the coach's agreement, the athletes under their supervision were invited to participate and made aware of the procedures. They agreed to participate voluntarily. All participants were recommended not to drink alcoholic beverages, food supplements, stimulants, or any other type of substance before the days of data collection, which was previously confirmed on each day of data collection. All athletes on the team agreed to participate in the study and before collecting data they and the respective guardians of the athletes under 18, signed a consent form. The inclusion criterion was to meet all the study requirements mentioned above. There was no exclusion of any participant from the sample.

Procedures

Data collection was carried out in two weeks. Physical tests were conducted in the first week, and in the second

one, judokas participated in the competition. The body composition assessment was performed on the first day, to characterize the sample, and the SJFT was performed 30min later. The SJFT and RAN were performed on that same week with an interval of 48 hours between tests. At the end of the second week, there was a qualifying competition for the finals of the State Championship. Participants were evaluated in the first fight (1-OC) of that competition, with the schedule for the whole week designed by the team coach. All tests were performed in the morning, between 9:00 am and 12:00 pm, including the 1-OC. The coach was present during the SJFT, RAN and 1-OC, encouraging athletes to try their best. HR, RPE and [La^-] were collected in the SJFT and RAN, while in the 1-OC, only RPE and [La^-] were collected since the competition organization had not authorized the use of the HR monitor.

Anthropometric Assessment

An anthropometric evaluation, which consisted of body mass and height measurement, was carried out to characterize the sample. Evaluation of fat percentage was made by double X-ray densitometry (DEXA) with the Discovery Wi device, (HOLOGIC INC, Bedford, USA), adopting all the procedures and guidelines of the manufacturer.

Special Judo Fitness Test (SJFT)

As proposed by Sterkowicz [1996], three judokas participated in the test, two sparrings (*ukes*) and the evaluated judoka (*tori*). The test was performed on a mat, using a distance of 6m. The evaluated judoka was in the center, 3m equidistant from the two sparrings. The test was divided into 3 periods: 15s, 30s and 30s, with a 10s interval between each. The purpose of the test was to throw sparrings as many times as possible, using the Ipon-Seoi-Nage move, alternating sparrings. The final HR was checked immediately after the test and after the first minute of recovery. The total number of throws was also counted, generating the following equation:

$$\text{SJFT Index} = \frac{\text{Final HR + HR 1min recovery}}{\text{Total number of throws}}$$

Randori (RAN)

The fight simulation was carried out between two judokas, at the venue where they trained. The division of pairs was carried out according to the weight and category of the athletes. The fight simulation had a duration of 4min timed, regardless if judokas achieved an Ippon, the score that indicates the end of the fight. The main coach of the team refereed the fight and the winner athlete was the one who accumulated the most points at the end of the allotted time.

Official competition (1-OC)

The judokas were evaluated in an official state-level competition organized by the State Federation, with fights lasting 4 minutes timed, according to the official rules of the sport. The data were collected only in the first fight of the competition, for each judoka, except for the fights completed by Ippon in less than 1 min. In such cases, the next fight was considered for evaluation.

Blood lactate ([La^-])

Blood samples for lactate analysis were collected at rest, after 1st, 3rd, 5th and 7th minutes of passive recovery in the three assessed situations. Twenty-five microliters (25 μL) were collected from the earlobe, in heparinized microcapillary tubes. The collected samples were placed in polyethylene micro tubes, Eppendorf type, with 50 μl of anticoagulant solution (sodium fluoride, 1%) and, later, analyzed with the lactate analyzer YSL 2300 (YSL, Ohio, USA).

Heart Rate (HR)

HR was monitored only in the SJFT and RAN, since the use of equipment by the judoka during the 1-OC had not been allowed. A sensor was attached to the judoka's chest with an elastic strap for HR recording. HR was recorded every second with the Polar Team System 2 heart rate monitor (Polar, Electro, Finland) and subsequently analyzed with the device's specific program.

Rated Perceived Exertion (RPE)

RPE was verified with the Borg Scale CR-10 [Borg 1982], in which athletes indicated their level of fatigue 20 minutes after the end of the efforts, on a scale of 1-10.

Statistical Analysis

The Shapiro-Wilk test was used to test the normality of data. After confirming the normality of the data, the HR of the RAN and SJFT were evaluated using the t-test for paired data and the [La^-] was evaluated by means of the analysis of variance for repeated measures among SJFT, RAN and 1-OC, with post-hoc by Newman Keuls. RPE was assessed using Freidman's non-parametric test, among SJFT, RAN and 1-OC. The relationship between the HR data and [La^-] was analyzed with Pearson's correlation and the relationship among RPE and the other variables through Spearman's correlation. The correlation was classified as (*r*): 0-0.1 very low; 0.1-0.3 low; 0.3-0.5 moderate; 0.5-0.7 high; 0.7-0.9 too high; 0.9-1.0 almost perfect [Hopkins 2000]. The effect size was calculated based on Cohen's d value for average values (d value). The result of d was qualitatively interpreted using the following classification: 0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; 2.0–4.0, very large; and .4.0, extremely large [Dankel *et al*. 2017]. The confidence interval was established at 95% [$CI_{95\%}$] and the level of significance adopted was 5% ($p < 0.05$). The analyzes were made with the statistics program JASP Team [2020] (JASP (Version 0.12.2).

Results

The characterization of the sample is shown in Table 1. The level of specific physical fitness of judokas classified by the index in the SJFT, both male and female, can be classified as regular, according to the classification proposed for Junior class athletes [Agostinho *et al.* 2018].

Table 1. Anthropometric and index characteristics in the SJFT.

	MALE	FEMALE	TOTAL
Age (years) [$CI_{95\%}$]	17.8 ± 0.8 (17.2 - 18.4)	18.3 ± 0.9 (17.6 - 19)	18 ± 0.9 (17.6 - 18.4)
Weight (kg) [$CI_{95\%}$]	68.1 ± 13.6 (59.7 - 76.5)	61.7 ± 12.4 (54.2 - 69.2)	65.3 ± 13.2 (57.2 - 73.4)
Fat (%) [$CI_{95\%}$]	12.3± 3.2 (8.4 - 16.2)	21 ± 5.6 (15.7 - 26.3)	16.1 ± 6.2 (10.2 - 22)
SJFT Index [$CI_{95\%}$]	12.9 ± 0.8 (12.3 - 13.5)	14.5 ± 1 (13.7 - 15.3)	13.7 ± 1.2 (13.2 - 14.4)

The results of the evaluations are shown in Table 2. [La^-] differed amongst the three situations, with higher values in the SJFT followed by the 1-OC and RAN: SJFT vs RAN (p <0.001, d = 1.79); SJFT vs 1-OC (p = 0.018, d = 0.75); RAN vs 1-OC (p = 0.020, d = 0.65). In relation to RPE, SJFT also presented higher values in relation to the 1-OC (p = 0.016, d = 0.82) and RAN ($p = 0.024$, d = 0.61), but with no difference between RAN and 1-OC ($p = 0.41$ d = 0.21). Both HR_{media} and HR_{max} did not differ between SJFT vs RAN: HR_{means} (p = 0.47, d = 0.19) and HR_{max} (p = 0.78, d = 0.07).

Table 2. Results of evaluations of the special judo fitness test (SJFT), randori (RAN) and official competition (1-OC).

	SJFT	**RAN**	**1-OC**
[La^-] (mmol · L^{-1}) [$CI_{95\%}$]	12.1 ± 2.3[b, c] (10.9 - 13.2)	7 ± 1.4[a, c] (6.3 - 7.7)	9.3 ± 3.1[a, b] (7.8 - 10.9)
RPE (ua) [$CI_{95\%}$]	6.6 ± 2.5[b, c] (5.4 - 7.9)	5 ± 2[a] (4.1 - 5.9)	4.4 ± 1.8[a] (3.6 - 5.3)
HR_{max} (bpm) [$CI_{95\%}$]	180 ± 16 (172 - 187)	181 ± 15 (174 - 189)	- -
HR_{med} (bpm) [$CI_{95\%}$]	162 ± 17 (153 - 170)	156 ± 20 (147 - 166)	- -
HR_{max} (%) [$CI_{95\%}$]	90.1 ± 5.4 (87.5 - 92.8)	86.4 ± 9.8 (81.6 - 91.2)	- -

Significant difference: $p < 0.05$. a ≠ SJFT; b ≠ RAN; c ≠ 1-OC. [La^-] = blood lactate concentration, RPE = rated perceived exertion, HR = heart rate.

There was a high statistically significant correlation between HR_{med} and RPE in the SJFT and between HR_{max} and [La^-] in the RAN (table 3). The correlations between RPE and [La^-] were very low in the SJFT and RAN and moderate in 1-OC. In the SJFT and RAN, HR_{max} had a low correlation with RPE. Also in the SJFT, there was a low correlation between HR_{max} and [La^-], as well as between HR_{med} and [La^-] in the RAN. Moderate correlations were found in the RAN, between HR_{med} and RPE and in the SJFT, between HR_{max} and [La^-].

Table 3. Correlations between RPE, [La^-], HR_{max} or HR_{med} in the Special Judo Fitness Test (SJFT), randori (RAN) and official competition (1-OC). Results expressed with values of *r.*

SJFT		
	[La^-]	HR_{max}
RPE	0.07 (p = 0.78)	0.19 (p = 0.47)
[La^-]	-	0.23 (p = 0.38)
RAN		
	[La^-]	HR_{max}
RPE	0.03 (p = 0.92)	0.25 (p = 0.36)
[La^-]	-	0.51* (p = 0.04)
1-OC		
	[La^-]	HR_{max}
RPE	0.4 (p = 0.13)	-
[La^-]	-	-

*Significant correlation at p <0.05. [La^-] = blood lactate concentration, RPE = rated perceived exertion, HR = heart rate.

Discussion

The aim of the present study was to verify the correlations amongst [La^-], HR and RPE in RAN, 1-OC and SJFT, and to compare the response of these variables in these three situations. The main findings of the study were that the SJFT showed greater intensity of effort, indicated by [La^-] and RPE, while both HR_{med} and HR_{max} did not differ among the three situations and the correlations did not show results uniform among the variables. [La^-] showed higher values in the SJFT, in relation to 1-OC and RAN, and [La^-] in 1-OC was higher than in the RAN. On the other hand, RPE was higher in the SJFT in relation to the RAN and 1-OC and there was no difference in RPE for the last two situations. HR_{med} and HR_{max} did not differ between the SJFT and RAN. These results reflected high and significant correlations between HR_{med} and RPE in the SJFT and between HR_{max} and [La^-] in the RAN. Moderate correlations were found between HR_{med} and RPE in the RAN and between [La^-] and SPE in the 1-OC. The other correlations among the variables studied were classified as low or very low.

SJFT was designed to simulate the high demand for the judo competition, with a greater proportion of the lactic anaerobic pathway, and short recovery intervals

to which the aerobic pathway contributes (15+30+30s of effort with 10s of recovery between efforts). However, the values of [La^-] in the SJFT were higher than those in the 1-OC, demonstrating that the test has a higher glycolytic demand, due to its characteristics. In the SJFT, the execution must be at maximum intensity throughout the 3 sets of the test, while in the competition the intensity varies according to the technical difference, strategy, time of fight and level of demand of the combat, with pauses commanded by the referee in several moments of the fight, including those for tidying up the Judogi. Such factors may explain the smaller [La^-] in the 1-OC. The literature presents results of [La^-] in the SJFT between 8-10.5 mmol.l^{-1} for male judokas [Franchini *et al.* 1998; Simao *et al.* 2016], reaching 13 mmol.l^{-1} in female judokas [Garbouj *et al.*, 2016], which are compatible with the data of the present study. In the situation of 1-OC, the [La^-] of judokas differs according to the competitive level: regional-state competition to [La^-] varies 6-9 mmol.l^{-1} [Nunes *et al.* 1998; Simao *et al.* 2016], a similar result to that found in the present study, while values between 10-13 mmol.l^{-1} were found in national and international competitions [Serrano *et al.* 2001; Obminski *et al.* 2010]. Therefore, we speculate that the judokas we evaluated in the present study would present higher [La^-] if the competition were at a higher level, i.e., the national championship.

In the comparison between the two fighting situations, 1-OC and RAN, [La^-] presented a higher value in 1-OC, possibly due to the difference between the requirement or demand of the two situations. Unlike the 1-OC, RAN is a daily activity and is usually performed between athletes on the same team. In addition, it is expected that the fighter's and his opponent's commitment as well as their motivation to fight in an official competition would be greater than that to fight in a training session. In fact, adrenergic and testosterone discharges are greater in competition compared to RAN training [Suay *et al.* 1999; Degoutte, Jouanel, Filaire 2003].

Other studies have demonstrated [La^-] between 8-18 mmol.l^{-1} after 1 RAN fight [Degoutte, Jouanel, Filaire 2004; Franchini *et al.* 2005; Bonitch-Dominguez *et al.* 2010; Bonitch-Gongora *et al.* 2012; Branco *et al.* 2013]. This great variation is related to the contextual variations of the fight, such as the difference in technical level and physical fitness, strategy, and the demand imposed by the opponent. In addition, a possible explanation for the [La^-] difference in RAN training is the situation in which it is performed. While in some studies the RAN was performed in daily training with judokas from the same team, in other studies the RAN occurred with athletes from different countries [Bonitch-Dominguez *et al.* 2010; Bonitch-gongora *et al.* 2012]. This second approach can motivate and/or demand greater intensity in training from the athlete, and consequently, increase the response of [La^-]. In practice, coaches should consider varying the opponents in the RAN training, and train with practitioners of other teams, so as to promote alternation of the intensity of this type of specific training. Based on our results and the literature, the RAN, as well as situational fighting training, or parts of the fight components, can be good training strategies to simulate the intensity of the competition, since the technical-tactical actions are present to be improved in a fighting situation, although, in the present study, RAN had lower values in [La^-] compared to 1-OC.

HR_{med} and HR_{max} did not differ between the SJFT and RAN. The registration of the HR in the 1-OC was not authorized by the competition organizing committee. However, some studies in judo competition reported HR_{med} of around 182 bpm [Degoutte, Jouanel, Filaire 2003] and HR_{max} of 195 bpm [Hernandez, Torres 2009]. During the RAN, HR_{max} was 181 bpm, similar to the values presented in other studies with simulated fights, 185 bpm in 3-7 RAN of 3min with 30s interval [Callister *et al.* 1991]; 188 bpm in interval attack training with opponent resistance (2 x 120s) and 191 bpm (1 x 120s RAN) in fight simulation or grip dispute situational training [Houvenaeghel *et al.* 2005]; 193 bpm in a protocol of four 5min fights, with 5min interval between them [Branco *et al.* 2013]. In our results, the HR_{med} in the RAN was 156 bpm, which is lower than that recorded after 1 RAN fight, lasting 5 min: 179 bpm [Branco *et al.* 2013] and higher than that recorded at the end of a 5 min RAN training session: 134 bpm [Bromley *et al.*, 2018]. It is possible to observe that the intensity of effort in the studies differs due to the characteristics of each training. In the present study, we characterize the effort intensity of the judokas with only 1 RAN, which can help in the development of different training models and strategies, varying the number of fights and the recovery time. Such an approach can be used in conjunction with other technical and tactical exercises, making it possible to modulate the intensity of the training session. In this case, the control of the internal load is very important.

[La^-] proved to be more sensitive in differentiating the three situations evaluated, presenting a higher value in the SJFT, followed by the 1-OC and RAN with less glycolytic requirement. In fact, [La^-] has been proposed as the most important indicator to quantify the level of effort in fights [Franchini *et al.* 2005; Simao *et al.* 2016; Torres-Luque *et al.* 2016], and our results corroborate this idea. RPE presented a response similar to that of [La^-] in the SJFT, as the most demanding situation; however, RPE did not differ between the RAN and 1-OC. On the other hand, HR was the worst parameter to discriminate the intensity among the evaluated situations, even though it had not been recorded in 1-OC. Therefore, although HR may be considered a good indicator of internal load in different sports and has already been investigated as a parameter in studies on intensity control in judo [Houvenaeghel *et al.* 2005; Branco *et al.*

2013], the use of HR in judo training should be taken with caution, being used in combination with other variables to monitor the internal training load. In fact, HR has been pointed out as a valid measure for endurance training, but not for short duration and high intensity intermittent efforts, with great anaerobic participation [Impellizzeri, Marcora, Coutts 2019].

The RPE was higher in the SJFT in relation to the RAN and 1-OC, while in the 1-OC it presented a lower value: 6.6 - "*Hard*"; 5 - *"Hard"*; 4.4 - *"Somewhat Hard"*, respectively. To our knowledge, no study has investigated RPE in the SJFT, perhaps, because RPE is not a predicted parameter for the analysis of the test. We verified RPE as an alternative parameter for the SJFT, with the intention of adding information to the test and in comparison, with RAN and 1-OC.

In previous studies, RPE was used in RAN sessions with similar results. RPE between 6 - *"Hard"* and 7 ua - *"Very Hard"* were reported after 4 fights of 5 min [Branco *et al.* 2013; Agostinho *et al.* 2015] and 5 - *"Hard"* to 7 ua -"*Very Hard*" after judo training sessions, whose main activity was RAN [Viveiros *et al.* 2011; Bromley *et al.* 2018]. Thus, we can state that RAN training usually presents RPE between *"Hard"* and "*Very Hard"*, which can be a facilitator for the coach when planning a RAN training session based on RPE. Nevertheless, the analysis of the internal load in an individualized way is still essential for the control of the training load. Another interesting point in the results was that there was no statistical difference between the RPE of the RAN (5 ua) and the 1-OC (4.4 ua), indicating that the RAN training, taking into account the RPE, can well simulate the requirements of 1-OC. However, the [La^-] response was greater in the 1-OC than RAN.

Few studies regarding RPE were conducted in competitions. Values of 7.3 ua - *"Very Hard"* - were found at the end of an official competition with 2 or 3 fights [Serrano *et al.* 2001]. Another study, which used the 6-20 Borg scale [1982], reported RPE of 12 "light" - and 14 ua -*"Hard"* - after the 1st fight and 13.5 -*"Somewhat Hard"* - and 15 ua - *"Hard"*- after 3 fights, for medalists and non-medalists, respectively, in a state-level competition [Kons *et al.* 2018]. This data is close to the present study: 4.4 ua - *"Somewhat Hard"*, after the 1st fight. Probably, in a complete competition, involving more than one fight, the RPE may be greater due to the accumulated fatigue between the fights and the expected technical balance in the most decisive stages of a competition, resulting in fights with greater time and physical demands. The technical level of the competition can also influence the RPE, since it seems that non-medal judokas report higher RPE than medal judokas, who, in theory, have a better technical-tactical level [Kons *et al.* 2018]. It is important to note that in the present study most of the judokas won their fights and qualified for the next stage of the competition.

There was a high and significant correlation between [La^-] and HR_{max} in the RAN. Although the [La^-] of the SJFT had been higher, with a significant difference in relation to the RAN, we did not find any difference between HR_{max} in the SJFT and RAN. So, even in a situation of greater intensity, confirmed by [La^-] and RPE, the HR_{max} showed similar results, indicating that, perhaps, both can estimate the HR_{max} of judokas, which would need to be proven with comparisons in other situations until exhaustion.

The RPE showed a high and significant correlation with the HR_{med} in the SJFT, being the situation in which there was a greater anaerobic request, which may explain the high correlation between these variables in the SJFT. In fact, the RPE seems to increase the greater the contribution anaerobic system, including being considered a more reliable measure of internal load in intermittent activities [Impellizzeri *et al.* 2004], while HR is a less valid indicator of internal load in short duration and in intermittent high intensity efforts [Impellizzeri, Marcora, Coutts 2019], a fact demonstrated in protocols with intermittent and continuous exercises [Drust, Reilly, Cable 2000]. In addition, it should be noted that the SJFT is a maximum assessment. Therefore, the correlation between RPE and HR_{med} has little practical relevance, which would be different if RPE had been significantly related to HR_{max}. In fact, our results demonstrate that RPE in SJFT is significantly higher than in the RAN. However, there is no difference between HR_{max} and HR_{med} for these situations, resulting in only low and moderate correlations, respectively, between these variables in the RAN situation, which corroborates other studies that did not find a significant correlation between RPE and HR_{max} or HR_{med} after 1 RAN fight. However, when RPE was analyzed at the end of several RAN, there was a significant correlation, ranging from moderate to high between RPE and HR [Bromley *et al.* 2018].

Although [La^-] and RPE discriminated the activity with the highest anaerobic demand - SJFT - these variables did not present high and significant correlations in any of the situations studied. On the other hand, high significant correlations were observed between RPE and [La^-] in studies in which these variables were measured at the end of several RAN [Branco *et al.* 2013; Bromley *et al.* 2018] or at the end of a competition [Serrano *et al.* 2001]. In our study, after 1-OC, we found a moderate and non-significant correlation between RPE and [La^-], a result that might have been different if the measurements were collected at the end of all the fights in the competition.

The lack of association among RPE and physiological variables can be explained by the complex afferent feedback system that mediates the perception of effort and the generation of fatigue [Noakes 2004]. The findings of the present study reinforce that metabolic stress and RPE can dissociate, being impossible to establish a causal

relationship between these variables [Marcora 2008; Moreira *et al.* 2012], when analyzing one fight only. In this sense, the low non-significant association between [La^-] and RPE can be motivated by acute responses with different sensitivities, with anaerobic solicitation being only one of the components of the response to RPE [Green *et al.* 2006]. Therefore, we cannot dismiss RPE as a useful parameter to control the training load and competitions in judo, as it can provide information beyond the physiological stress, since the training load is not composed only by the physiological demand [Impellizzeri, Marcora, Coutts 2019]. Importantly, the RPE was able to discriminate the situation with higher anaerobic demand in the present study.

In other studies, the correlations analyzed in only one RAN fight and in 1-OC presented different results from those observed with the accumulation of fights during the RAN training and the competition [Bromley *et al*. 2018], as it occurs in daily training with varying physical, technical and tactical stimuli combined, usually lasting more than an hour. The accumulation of fights can alter the results found in relation to RPE, as well as interfere with the concentration of [La^-] and HR variation and, consequently, in the correlations between these variables, as verified in some studies with judo [Branco *et al*. 2013; Serrano *et al*. 2001]. Thus, future studies that compare training sessions and complete competitions to 1 RAN and 1-OC among the same judokas can add more information on the best variables to be used in the control of the training load. On the other hand, our results confirm that [La^-] was the most sensitive physiological parameter for identifying effort in specific judo actions, which was not observed with HR.

Conclusion

Among the evaluated parameters, [La^-] was the most sensitive to discriminate the intensity of actions in the three situations evaluated: RAN, OC and SJFT, while HR_{med} and HR_{max} did not differ significantly in the two assessments (SJFT and RAN). RPE of the athletes was higher in the SJFT, differing from RAN and 1-OC, but presented a low correlation with HR_{max} in the RAN and with [La^-] in the SJFT and RAN, in addition to a moderate correlation with [La^-] in the OC. However, high correlations were detected in the RAN, between [La^-] and $HR_{max,}$ and in the SJFT, between RPE and HR_{med}. Therefore, HR_{max} was only related to [La^-] in the situation with the lowest anaerobic demand and HR_{med} only related to RPE in the most anaerobic demanding situation.

In short, for the category studied, [La^-] best discriminated the specific actions of judo, the HR did not seem to be a good indicator of the intensity of the specific activities of judo, while more studies with RPE in training sessions and complete competitions must be held to add new information to the results found.

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References

1. Agostinho M.F., Olivio Jr J.A., 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.
2. Agostinho M.F., Philippe A.G., Marcolino G.S., Pereira E.R., Busso T., Candau R., Franchini E. (2015), *Perceived Training Intensity and Performance Changes Quantification in Judo*, "The Journal of Strength and Conditioning Research", vol. 29, no. 6, pp. 1570–1577.
3. Bonitch-Dominguez J., Bonitch-Gongora J., Padial P., Feriche B. (2010), *Changes in peak leg power induced by successive judo bouts and their relationship to lactate production*, "Journal of Sports Sciences", vol. 28, no. 14, pp. 1527–1534; doi: 10.1080/02640414.2010.512641.
4. Bonitch-gongora J.G., Bonitch-Dominguez J.G., Padial P., Feriche B. (2012), *The Effect of Lactate Concentration on the Handgrip Strength During Judo Bouts*, "The Journal of Strength and Conditioning Research", vol. 26, no. 7, pp. 1863–1871; doi: 10.1519/JSC.0b013e318238ebac.
5. Borg G.A.V. (1982), *Psychophysical bases of perceived exertion*, "Medicine & Science in Sports & Exercise", vol. 14, no. 5, pp. 377–381.
6. Branco B.H.M., Andreato L.V, Marinho B.F., Miarka B., Monteiro L., Franchini E. (2013), *Association between the Rating Perceived Exertion, Heart Rate and Blood Lactate in Successive Judo Fights (Randori)*, "Asian Journal of Sports Medicine", vol. 4, no. 2, pp. 125–130.
7. 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", vol. 21, pp. 1008–1012.
8. Callister R., Callister R.J., Staron R.S., Fleck S.J., Tesch P., Dudley G.A. (1991), *Physiological characteristics of elite judo athletes*, "International Journal of Sports Medicine", vol. 12, no. 2, pp. 196–203.
9. Casals C., Huertas J.R., Barranco-Ruiz Y., Escobar-Molina R. (2016), *Physiological responses to the special judo fitness test in elite Spanish judo athletes: a new monitoring approach*, "Revista de Artes Marciales Asiaticas", vol. 11, no. 2s, pp. 24–25; doi: 10.18002/rama.v11i2s.4154.
10. Dankel S.J., Mouser J.G., Mattocks K.T., Counts B.R., Jessee M.B., Buckner S.L., Loenneke J.P. (2017), *The widespread misuse of effect sizes*, "Journal of Science and Medicine

in Sport", vol. 20, no. 5, pp. 446–450; doi: 10.1016/j.jsams.2016.10.003.
11. Degoutte F., Jouanel P., Filaire E. (2003), *Energy demands during a judo match and recovery*, "British Journal of Sports Medicine", vol. 37, no. 1, pp. 245–249; doi: 10.1136/bjsm.37.3.245.
12. Degoutte F., Jouanel P., Filaire E. (2004), *Mise en evidence de la sollicitation du cycle des purines nucleotides lors d'un combat de judo*, "Science and Sports", vol. 19, no. 1, pp. 28–33; doi: 10.1016/S0765-1597(03)00162-X.
13. Drust B., Reilly T., Cable N.T. (2000), *Physiological responses to laboratory-based soccer-specific intermittent and continuous exercise*, "Journal of Sports Sciences", vol. 18, no. 11, pp. 885–892; doi: 10.1080/026404100750017814.
14. Franchini E., Artioli G.G., Brito J.C. (2013), *Judo combat: Time-motion analysis and physiology*, "International Journal of Performance Analysis in Sport", vol. 13, no. 3, pp. 624–641.
15. Franchini E., Del Vecchio F.B., Sterkowicz S. (2009), *A special judo fitness test classificatory table*, "Archives of Budo", vol. 5, pp. 127–129.
16. Franchini E., Nakamura F.Y., Takito M.Y., Kiss M.A.P.D.M., Sterkowicz S. (1998), *Specific fitness test developed in Brazilian judoists*, "Biology of Sport", vol. 15, no. 3, pp. 165–170.
17. Franchini E., Nunes A.V., Moraes J.M., Del Vecchio F.B. (2007), *Physical Fitness and Anthropometrical Profile of the Brazilian Male Judo Team*, "Journal of Physiological Anthropology", vol. 26, no. 2, pp. 59–67; doi: 10.2114/jpa2.26.59.
18. Franchini E., Takito M.Y., Bertuzzi R.C. de M., Kiss M.A.P.D. (2004), *Competitive level, type of recovery and blood lactate removal after a judo match*, "Revista Brasileira de Cineantropometria e Desempenho Humano", vol. 6, no. 1, pp. 7–16 [in Portuguese].
19. Franchini E., Takito M.Y., Kiss M.A.P.D.M., Sterkowicz S. (2005), *Physical Fitness and Anthropometrical Differences Between Elite and Non-Elite Judo Players*, "Biology of Sport", vol. 22, no. 4, pp. 315–328.
20. Garbouj H., Selmi H.A., Sassi R.H., Yahmed M.H., Chamari K., Chaouachi A. (2016), *Do maximal aerobic power and blood lactate concentration affect Specific Judo Fitness Test performance in female judo athletes ?*, "Biology of Sport", vol. 33, no. 2, pp. 367–372; doi: 10.5604/20831862.1221890.
21. Green J.M., McLester J.R., Crews T.R., Wickwire P.J., Pritchett R.C., Lomax R.G. (2006), *RPE association with lactate and heart rate during high-intensity interval cycling,* "Medicine and Science in Sports and Exercise", vol. 38, no. 1, pp. 167–172; doi: 10.1249/01.mss.0000180359.98241.a2.
22. Hernandez R., Torres G. (2009), *Fighting in the judo competition individuals and teams: differences in temporary structure,* "Journal of Sport and Health Research", vol. 1, no. 1, pp. 5–11.
23. Hopkins W.G. (2000), *Measures of Reliability in Sports Medicine and Science*, "Sports Medicine", vol. 30, no. 1, pp. 1–15.
24. Houvenaeghel M., Bizzari C., Giallurachis D., Demelas J.M. (2005), *Mesure continue de la frequence cardiaque en entrainement specifique de judo*, "Science and Sports", vol. 20, no. 1, pp. 27–32; doi: 10.1016/j.scispo.2004.05.009.
25. Impellizzeri F.M., Marcora S.M., Coutts A.J. (2019), *Internal and External Training Load: 15 Years On*, "International Journal of Sports Physiology and Performance", vol. 14, no. 2, pp. 270–273; doi: 10.1123/ijspp.2018-0935.
26. Impellizzeri F.M., Rampinini E., Coutts A.J., Sassi A., Marcora S.M. (2004), *Use of RPE-based training load in soccer*, "Medicine and Science in Sports and Exercise", vol. 36, no. 6, pp. 1042–1047; doi: 10.1249/01.MSS.0000128199.23901.2F.
27. Kons R.L., Dal Pupo J., Ache-Dias J., Garcia T., Rodrigues da Silva R., Katicips L.F.G., Detanico D. (2018), *Effect of official judo matches on handgrip strength and perceptual responses*, "Journal of Exercise Rehabilitation", vol. 14, no. 1, pp. 93–99; doi: 10.12965/jer.1835156.578.
28. Marcora S.M. (2008), *Do we really need a central governor to explain brain regulation of exercise performance?*, "European Journal of Applied Physiology", vol. 104, no. 5, pp. 929–931; doi: 10.1007/s00421-008-0818-3.
29. Miarka B., Fukuda D.H., Del Vecchio F.B., Franchini E. (2016), *Discriminant analysis of technical-tactical actions in high-level judo athletes*, "International Journal of Performance Analysis in Sport", vol. 16, no. 1, pp. 29–39.
30. 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.
31. Moreira A., McGuigan M.R., Arruda A.F.S., Freitas C.G. de, Aoki M.S. (2012), *Monitoring internal load parameters during simulated and official basketball matches*, "The Journal of Strength and Conditioning Research", vol. 26, no. 3, pp. 861–866.
32. Noakes T.D. (2004), *Letter To The Editor: Linear relationship between the perception of effort and the duration of constant load exercise that remains*, "International Journal of Phytoremediation", vol. 91, no. 1, pp. 135–136; doi: 10.1080/13518040701205365.
33. Nunes A.V., Andrade R. de, Paiva C.R.E., Klemt U.G. (1998), *Blood lactate in judo athletes: report of the collection experience during successive combats in an official competition*, "Revista Brasileira de Medicina Do Esporte", vol. 4, no. 1, pp. 20–23[in Portuguese]; doi: 10.1590/s1517-86921998000100006.
34. Obminski Z., Lerczak K., Witek K., Pintera M. (2010), *Studies on lactate peak in blood following judo match*, "Journal of Combat Sports and Martial Arts", vol. 1, no. 2, pp. 95–99.
35. Salvador A., Suay F., Martinez-Sanchis S., Simon V.M., Brain P.F. (1999), *Correlating testosterone and fighting in male participants in judo contests*, "Physiology & Behavior", vol. 68, pp. 205–209.
36. Serrano M.A., Salvador A., Gonzalez-Bono E., Sachis C., Suay F. (2001), *Relationships between recall of perceived exertion and blood lactate concentration in a judo competition*, " Perceptual and Motor Skills", vol. 92, no. 2, pp. 1139–1148.
37. Simao A.A.G., Aidar F.J., Guimaraes C.F., de Matos D.G., Pereira A.R., Almeida Junior H., Bastos A.A. (2016), *Blood lactate assessment in Judo: Relation between specific test*

and combat situation, "Motricidade", vol. 11, no. S1, pp. 153–160 [in Portuguese].
38. Sterkowicz S. (1996), *Poszukiwaniu nowego testu specjalnej sprawności ruchowej w judô*, "Trening", vol. 3, pp. 46–60.
39. Sterkowicz S., Franchini E., Heinisch H. (2005), *Special Judo Fitness Test performance in high level judo players*, "In International Judo Federation 2005 World Judo Research Symposium", Cairo, pp. 49.
40. Sterkowicz S., Zuchowicz A., Kubica R. (1999), *Levels of Anaerobic and Aerobic Capacity Indices and Results for the Special Fitness Test in Judo Competitors*, "Journal of Human Kinetics", vol. 21, no. 2, pp. 115-135.
41. Torres-Luque G., Hernandez-Garcia R., Escobar-Molina R., Garatachea N., Nikolaidis P.T. (2016), *Physical and Physiological Characteristics of Judo Athletes : An Update*, "Sports", vol. 4, no. 20, pp. 1–12; doi: 10.3390/sports4010020.
42. Viveiros L., Costa E.C., Moreira A., Nakamura F. Y., Aoki M.S. (2011), *Judo Training Monitoring: Comparison between the Coach's Planned Load Intensity and the Athlete's Perceived Intensity*, "Revista Brasileira de Medicina Do Esporte", vol. 17, no. 12, pp. 266–269 [in Portuguese].

Analiza reakcji mleczanowych, częstość akcji serca i oceny odczuwalnego wysiłku w randorii, w zawodach oraz specjalnym teście sprawnościowym judo

Słowa kluczowe: judo, obciążenie wewnętrzne, mleczan we krwi, tętno, ocena odczuwanego wysiłku

Streszczenie

Tło: Obecność mleczanu we krwi [La-], częstość akcji serca (HR) i ocena odczuwanego wysiłku (RPE) są wykorzystywane do ilościowego określenia intensywności wysiłku w judo.
Problem i Cel. Zależność pomiędzy zmiennymi [La-], HR i RPE po pierwszej walce w oficjalnych zawodach (1-OC), po jednej rundzie Randori (RAN) i *Special Judo Fitness Test* (SJFT) nie były badane łącznie. Dlatego też celem niniejszej pracy było sprawdzenie korelacji pomiędzy stosunkiem mleczanu we krwi, częstości akcji serca i oceną odczuwanego wysiłku w Randorii, w oficjalnych zawodach i teście SJFT oraz zmiany tych zmiennych w tych trzech warunkach.
Metody. Próba składała się z 16 judoków na poziomie państwowym i krajowym, 8 mężczyzn i 8 kobiet, wiek: 18 ± 0,9 lat. Ocenę antropometryczną, SJFT i RAN przeprowadzono w pierwszym tygodniu, a w drugim tygodniu judocy uczestniczyli w zawodach. W SJFT i RAN zbierano dane: częstość akcji serca, ocena odczuwanego wysiłku i mleczan we krwi, natomiast w oficjalnych zawodach tylko częstość akcji serca i mleczan we krwi.
Wyniki. Wartość mleczanu we krwi różniła się pomiędzy trzema sytuacjami, z wyższymi wartościami w SJFT, a następnie w 1-OC i RAN. W odniesieniu do oceny odczuwanego wysiłku, SJFT również prezentował wyższe wartości w stosunku do 1-OC. Stwierdzono wysoką korelację między HRmed i RPE w SJFT oraz między HRmax i [La-] w RAN.
Wnioski. Dla badanej kategorii mleczan we krwi najlepiej określał specyficzne działania w judo, podczas gdy częstość akcji serca nie wydaje się być dobrym wskaźnikiem intensywności specyficznych działań w judo. Należy przeprowadzić więcej badań z oceny odczuwanego wysiłku w sesjach treningowych i pełnych zawodach, aby dodać nowe informacje do znalezionych wyników.