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Research article

Does The Timing of Measurement Alter Session-RPE in Boxers?

Marco C. Uchida [1]✉, Luis F. M. Teixeira [2], Vladmir J. Godoi [3], Paulo H. Marchetti [4,8] , Marcelo Conte [3,5], Aaron J. Coutts [6] and Reury F. P. Bacurau [7]

[1] Faculty of Physical Education, State University of Campinas, Campinas, Brazil; [2] Faculty of Physical Education - UNIFIEO, Osasco, Brazil; [3] Faculty of Physical Education, Anhanguera Educational, Sorocaba, Brazil; [4] Methodist University of Piracicaba, Piracicaba, Brazil; [5] School of Physical Education of Jundiaí, Jundiaí, Brazil; [6] Faculty of Health, University of Technology Sydney, Sydney, Australia; [7] School of Arts, Sciences and Humanities, University of São Paulo, São Paulo, Brazil; [8] Faculty of Physical Education, YMCA, Sorocaba, Brazil

Abstract

The purpose of this study was to compare the influence of measuring the overall session rating of perceived exertion (session-RPE) at 10 vs. 30 minutes following exercise. Eight boxers completed three different standardized training sessions of different intensities (easy, moderate and hard) in a matched-pairs, randomized research design. Exercise intensity was assessed during each bout by measuring heart rate, blood lactate concentration and session-RPE. To assess the effect of measurement timing on session-RPE, RPE data were collected either 10 or 30 minutes post-exercise. There was no significant effect of measurement time on session-RPE values following easy (10 minutes: session-RPE = 1.3 ± 1.0 Arbitrary Unit (AU), %Heart Rate Reserve (HRR) = 49.5 ± 11.1, and ΔBlood lactate = -2.3 ± 16.3%; 30 minutes: session-RPE = 1.7 ± 1.0 AU, %HRR = 51.3 ± 10.8, and ΔBlood lactate = 0.7 ± 25.2%), moderate (10 minutes: session-RPE = 2.7 ± 1.6 AU, %HRR = 67.2 ± 10.8, and ΔBlood lactate = 2.2 ± 19%; 30 minutes: session-RPE = 2.5 ± 0.9 AU, %HRR = 67.2 ± 5.9, and ΔBlood lactate = 24.5 ± 17.1%) and hard (10 minutes: session-RPE = 5.7 ± 1.0 AU, %HRR = 88.1 ± 6.3, and ΔBlood lactate = 146.3 ± 87.9%; 30 minutes: session-RPE = 5.8 ± 1.9 AU, %HRR = 83.3 ± 8.0, and ΔBlood lactate = 91.6 ± 39%) sessions. In conclusion, our findings suggest that session-RPE can be used in boxing training routines across a range of intensities and accurate measurements can be determined as early as 10 minutes after exercise.

Key words: boxing, perceived exertion, internal load, lactate, combat sports, exercise intensities.

Introduction

Boxing is a combat sport that requires the unique combination of well-developed hand and foot speed, footwork, evasion skills, muscular strength and power as well as a high aerobic capacity (Zazryn et al., 2006). Boxing matches are won either by the participants who score more points (i.e. landing legal punches) or when the opponent is unable to continue to fight (Zazryn et al., 2006). Previous studies have demonstrated that boxers with great physiological capacities such as a high individual anaerobic threshold and hand grip strength typically have a better competitive ranking (Guidetti et al., 2002). However, these physiological aspects are not the only determinants of optimal performance in boxing. In fact, such performance depends on a combination of technical skills, psychological and physiological aspects (Guidetti et al., 2002) and this complexity makes it difficult to quantify the training load in boxing.

Although each boxing training session will vary in content according to the training objectives, it generally consists of activities such as warm-up, rope skipping, skill development boxing exercises, bag punching drills and sparring with partners. Due to the combative nature of boxing, it is difficult to assess exercise intensity during these sessions using traditional objective methods such as heart rate monitors or other microtechnology devices (i.e. GPS, accelerometers etc.), as these devices may interfere with training, especially during sparring. In fact, a common problem for coaches and scientists working with boxing is the difficulty in quantifying training load.

Accurate measurements of training load are essential in a well-controlled training plan (Banister et al., 1975). At present, no studies have investigated the most appropriate methods for quantifying training load in boxing. However, the session rating of perceived exertion (session-RPE) method (Foster et al., 2001) for quantifying training load has shown to be valid for many sports, including soccer (Alexiou and Coutts, 2008; Impellizzeri et al., 2004), Australian football (Scott et al., 2013), taekwondo (Haddad et al., 2011), cycling (Foster et al., 2001), swimming (Wallace et al., 2009) and resistance training (Day et al., 2004; Singh et al., 2007). This method uses a modified version of Borg's CR-10 scale (Borg et al., 1985) of perceived exertion as a measure of intensity to quantify the training doses. Athletes provide a session-RPE measure 30 minutes after bout by rating their perception of effort for an entire session, and this rating can be multiplied by the training session duration in minutes to provide session RPE method (internal training load). The rationale behind the 30 minutes period before the session-RPE collection is that either easy or hard exercise periods near the termination of the exercise sessions may have a 'recency' effect on global RPE measures if completed at the end of the session (Foster et al., 2001). Hornsby and colleagues (2013) indicated, in a recent publication, that session-RPE is not linked to terminal acute RPE. Presently, it is unknown if reporting session-RPE earlier (10 minutes after completing each training session) could alter the training load score. Indeed, the 30 minutes time delay required to assess session-RPE is generally considered a practical limitation of this approach, as it increases time demand on athletes.

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Thus, the first aim of the present study was to verify if session-RPE estimations obtained 10 minutes after boxing training sessions of different intensities differed from session-RPE taken after 30 minutes. We hypothesized that a reduced period between the training session and providing the session-RPE measurement would not affect with the result. The second aim was to determine whether session-RPE measurements could be used to identify different intensity training sessions in boxing.

Methods

Subjects

Eight male Olympic boxing athletes (age = 18.8±1.8 years; height = 1.71 ± 0.09 m; body mass=66.7 ± 16.5 kg) from the same boxing team volunteered to participate in this study. No participants reported any history of injury within one year before recruitment. All athletes were tested during the preparation phase (i.e. mesocycle) of the training calendar. Each participant had at least four years of boxing experience, and typically performed three boxing-specific training bouts (2 hours) each week. All participants were informed about the aims and risks of participating in the present study and signed an informed consent document before engaging in the study. The study was approved by the Ethics Committee of the School of Physical Education of Jundiaí (ESEF).

Experimental design

Initially, a pilot study was conducted to evaluate the exercise intensities of boxing sessions (i.e. easy, moderate and hard) according to the session-RPE scale. This pilot study revealed differences in session-RPE values among the three different groups, and demonstrated that different cadences of boxing movements could be used to modulate session-RPE in boxing. Prior to the pilot study, all athletes were familiarized with the RPE scale (Borg's CR10-Scale) and had completed over 20 regular training sessions using session-RPE. According to the methods of Foster et al. (2001), 30 minutes after each session athletes estimated RPE according to the session-RPE method. In this study, the Portuguese translation of the RPE method modified by Foster et al., (2001) was used.

This study used a randomized, matched pairs cross-over research design. That is, pairs performed all the bouts of different intensities for 45 minutes each and post exercise session-RPE was collected after 10 minutes or 30 minutes. Following the pilot study, participants were divided into four pairs (i.e. training partners) according to their boxing ability. Each pair was randomly assigned to complete an easy, moderate or hard training session, which was closely supervised by one of the investigators. Each boxing session was matched for training content (i.e. components of the training sessions) and the intensity was altered by manipulating the cadence of the boxing movements. The subjects were not informed about the intensity of the training prior to each session and sessions were completed in a random order (Table 1). The feedback about frequency/cadence of the boxing activities (i.e. slower or faster) was the only information athletes received from the researchers during training sessions.

Heart rate (HR) was measured at rest (HR_r) with an HR monitor (FS2C, Polar Electro Oy, Kempele, Finland) at every minute during all sessions. The average HR of each training session (HR_{AVER}) and the relative intensity in each exercise bout ($\%HR_r$) was calculated using the formula (Desgorces et al., 2007):

$$\%HR_r = [(HR_{AVER} - HR_r) / (HR_{Max} - HR_r)] / 100$$

Each athlete completed six training sessions of 45 minutes and the same combination of exercises. The six training sessions were: three different intensities (easy, moderate and hard) and two RPE collection time (10 or 30 minutes) for each session. However, session intensities were collected at different times (e.g. athlete "A" within pair "1" performed the moderate intensity training with RPE obtained 10 minutes following training on Monday [first week]; the same intensity was performed by this athlete on Friday [second week], but RPE data were obtained 30 minutes following training). All training sessions were completed between 0700 and 0900 hours in a randomized order. The participants were given 48 hours rest period between each session to ensure their adequate rest and they were also asked to standardize food and fluid intake for 12 hours prior to testing.

Physical training

The standardized warm-up consisted of 5 minutes of traditional boxing movements at very light intensity. Following warm-up, all participants completed a 40 minutes boxing training (i.e. 4 x 10 minutes). To achieve strong ecological validity with the experimental design, each 10 minutes bout consisted of 4 x 2 minutes efforts,

Table 1. Description of easy, moderate, and hard training intensities session (4 rounds/exercise).

	Planned Intensity					
	Easy		Moderate		Hard	
Exercise	Cadence	Duration (min)	Cadence	Duration (min)	Cadence	Duration (min)
Time Session (min)	45		45		45	
Warm up	--	5	--	5	--	5
Rope Jump	75	10	125	10	180	10
Skill development boxing exercises (UpL/LoL)	60/30	10	120/60	10	180/90	10
Bag Drill (Punch)	30	10	60	10	90	10
Shadow - Simulated Fight (UpL/LoL)	60/30	10	120/60	10	180/90	10

Cadence : [volume (number of movements/round)/minute]. 1 round : 2minutes with 30seconds of rest interval. UpL/LoL: Upper limbs/Lower limbs

Table 2. Sequence of data collection during each test session.

	Sequence of Measurements	Duration (minutes)
Pre-Training	1. Reception and Preparation of Athletes	10
	2. Rest	10
	3. Heart Rate	1
	4. Blood Lactate	1
	5. Push-Up Performance	.5
Training Session	6. Heart Rate (min by min)	45
Post-Training	7. Blood Lactate	1
	8. Push-Up Performance	.5
	9. Session-RPE	10 or 30 (after session)

with a 30 seconds passive recovery. Each 2 minutes effort included rope jump, boxing exercises for skill development, bag drills (punching) and shadow (simulated fighting).

Parameters for determination of the internal load of training session

The internal load was calculated using both the session-RPE method (Foster et al., 2001) and training impulse (TRIMP) (Banister et al., 1975). The HR collected during each training session was used to calculate the TRIMP according to the following formula (Banister et al., 1975):

$$TRIMP = \text{training volume} * [(HR_{AVER} - HR_r) / (HR_{máx} - HR_r)] * 0.64 \exp [(HR_{AVER} - HR_r) / (HR_{máx} - HR_r) * 1.92].$$

Table 2 shows the sequence of data collection in pre, during and post training session.

Physiological and physical performance data collection

Blood lactate was measured before and immediately after each training session from capillarized blood (20 µL) using an Accutrend Lactate analyzer (Roche®, Sao Paulo, Brazil). To compare the intensity of each training session, the percentage of change in blood lactate concentration (ΔLactate) was determined for each session (i.e. easy, moderate and hard).

A push-up test was performed before and after the training sessions in order to evaluate a decline in physical performance after each exercise session. Athletes were instructed to perform the maximal number of push-ups in 30 seconds. During the test, participants were asked to keep their hands in contact with the floor, and arms as close as possible (parallel) to the trunk. To standardize the test, the upper limbs were kept at the biacromial distance. This technique provided a pattern of push-up movements that was similar to the punch during boxing. These pre and post tests were used to determine the variation in the push-up performance (ΔAF) at different intensities (i.e. easy, moderate and hard).

Statistical analyses

Normality and homogeneity of variance of the data were confirmed by the Shapiro-Wilk and Levene tests, respectively. Data were expressed as means ± standard deviation. For the analysis of dependent variables, ANOVA (3x2) repeated measures was employed using training intensity (easy, moderate and hard) and time of recovery (10 and 30 minutes) as factors. Post hoc comparisons were performed using the Tukey test. The effect size (ES) with 95% confidence intervals was calculated using Cohen *d* and the ICC was used to test reliability-validity. An alpha of 0.05 was used for all statistical tests that were performed using GraphPad-Prism (Graphpad software, Inc, USA).

Results

Table 3 shows the values of Session-RPE, Session-RPE load and TRIMP, obtained 10 or 30 minutes after easy moderate and hard intensity training.

Session-RPE, Session-RPE load and TRIMP values are directly correlated to training intensity taken at 10 or 30 minutes ($p < 0.05$, Table 3). However, Session RPE measures taken at 10 and 30 minutes were not statistically different when subjects performed bouts of the same intensity. Similarly, no difference was observed in session-RPE load measures among groups (10 vs. 30 minutes), although session-RPE load was different among the easy, moderate and hard sessions ($p < 0.001$).

Table 3. Session-RPE (10 minutes and 30 minutes), Session-RPE load, TRIMP during the training intensities (Easy, Moderate and Hard) and effect size between 10 minutes and 30 minutes. Data are means (± standard deviation).

		Training Intensity		
		Easy	Moderate	Hard
Session-RPE (AU)	10 minutes	1.3 (1.0)	2.7 (1.6)	5.7 (1.0) *
	30 minutes	1.7 (1.0)	2.5 (0.9)	5.8 (1.9) * †
	Effect Size	.39	- .15	.06
Session-RPE Load (AU)	10 minutes	61.8 (47.7)	118.1 (67.7)	258.7 (46.5) *†
	30 minutes	78.7 (46.5)	112.5 (41.6)	264.3 (88.1) *†
	Effect Size	.35	- .09	.07
TRIMP (AU)	10 minutes	35.8 (12.4)	79.4 (29.6)	151.6 (21.6) *
	30 minutes	38.2 (12.7)	76.9 (11.6)	123.6 (28.9) *
	Effect Size	.19	.02	- 1.09

RPE = Rating of Perceived Exertion; AU = Arbitrary Unit. Effect Size between 10 minutes and 30 minutes.
* Different from Easy training intensity ($p < 0.05$). † Different from Moderate training intensity ($p < 0.05$)

Table 4. Heart Rate (bpm) in the different exercises that made up the training sessions. Data are means (± standard deviation).

	Training Sessions					
	Easy		Moderate		Hard	
Exercise	10 min	30 min	10 min	30 min	10 min	30 min
Warm up	94.0 (11.0)	93.9 (11.1)	93.8 (9.5)	98.5 (8.0)	98.2 (11.7)	99.3 (14.1)
Rope Jump	125.1 (10.9)*	126.1 (6.3)*	129.5 (18.3)*	146.3 (8.9)*	166.2 (18.6)*	153.8 (13.0)*
Skill development boxing exercises	125.3 (4.8)*	129.7 (3.1)*	157.3 (12.0)*	156.7 (6.6)*	182.4 (5.5)*	170.7 (5.8)*
Bag Drill (Punch)	136.1 (9.2)*†‡	139.7 (9.2)*†‡	172.7 (4.9)*†	166.3 (3.8)*†	187.3 (5.1)*	181.0 (6.7)*
Shadow - Simulated Fight	136.2 (4.7)*†‡	137.0 (5.1)*†‡	166.3 (7.4)*†	162.2 (7.6)*†	187.5 (3.8)*	181.3 (4.4)*

bpm = beats per minute. * Different from warm up value ($p < 0.05$). † Different from rope jump value ($p < 0.05$). ‡ Different from skill development boxing exercises value ($p < 0.05$).

There were significant TRIMP differences between the easy sessions compared to hard sessions ($p < 0.001$). However, there was no statistical difference between moderate and easy or hard sessions ($p > 0.05$), and between RPE measures taken at 10 and 30 minutes ($p > 0.05$) (Table 3).

The mean HR during training session was significantly different among the three planned intensities ($p < 0.001$). Post-hoc analyses showed that HR during the easy session was lower than the hard session ($p < 0.001$). Similarly, the % HR reserve was significantly different between the easy, moderate and hard training sessions ($p < 0.001$). However, there was no difference between RPE measures taken 10 or 30 minutes following the session ($p > 0.05$, Figure 1a).

There were significant differences in blood lactate concentration between the easy, moderate and hard sessions ($p < 0.05$), but there was no influence of timing on RPE measurement ($p > 0.05$, Table 5). Similarly, the change in push-up test performance was different between the easy and hard sessions ($p < 0.01$), but no difference was seen between the 10 and 30 minutes sessions, as shown in Figure 1b.

Because the latency or recent effects of hard and easy bouts within a session could influence the overall session-RPE, HR values between boxing activities were recorded (Table 4).

Discussion

The session-RPE method has been developed and validated as a simple method to quantify training internal load in athletes in a variety of sports. The original method recommends that RPE measures should be taken approximately 30 minutes following exercises to avoid the temporal latency or recent effects of either easy or hard bouts of exercise within a training session (Foster et al., 2001). However, this delay in measurement is often impractical in many situations (Singh et al., 2007). Therefore, the purpose of this study was to verify if the timing of session-RPE measurement influenced athlete's perception of session intensity when taken at 10 and 30 minutes following exercise. The main findings of this study showed that session-RPE measures were not statistically different when obtained after 10 or 30 minutes in boxing routines of the same intensity.

A novel finding from this study was that session-RPE estimations were not significantly different when taken 10 or 30 minutes after easy, moderate and hard boxing sessions (Table 3). In contrast to our study, other groups had have shown previously that RPE taken at 5 and 10 minutes following resistance training sessions were different from the values obtained at 30 minutes (Singh et al., 2007). Besides the obvious differences in the exercise modes between these studies (i.e. boxing vs.

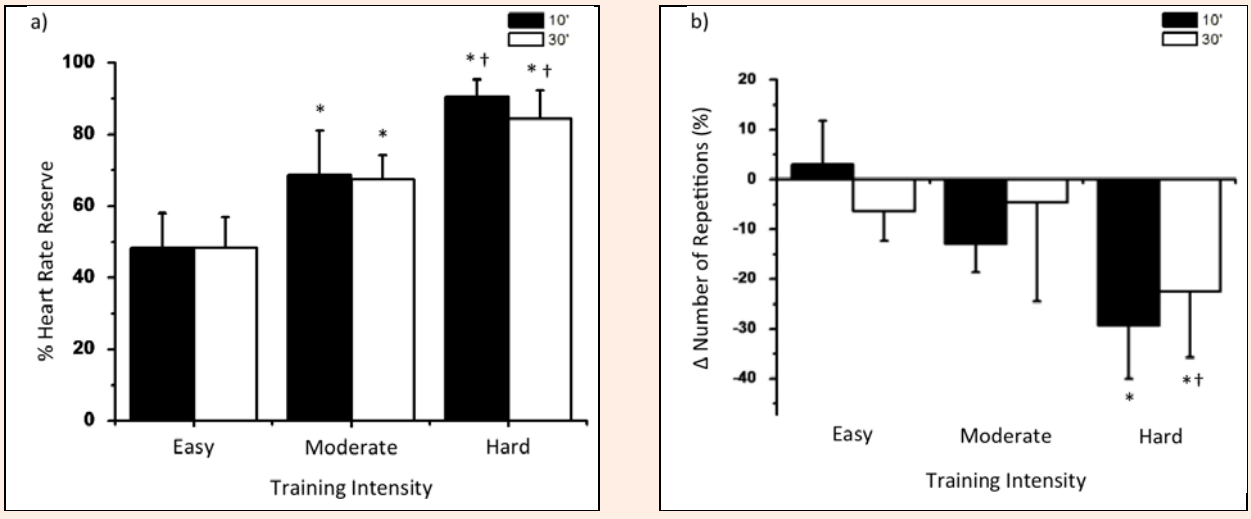

Figure 1. Mean (±) standard deviation of the: (a) % heart rate reserve; (b) percent variation in number of repetition in push-up. RPE collection time 10 and 30 minutes after the training intensities (Easy, Moderate and Hard). * Different from easy training intensity and † different from moderate training intensity, ($p < 0.05$).

Table 5. Blood lactate concentration: before and after the training sessions (Easy, Moderate and Hard). Data are means (± standard deviation).

Training Intensities	Measure of Perception after (min)	Pre Lactate ($mmol \cdot l^{-1}$)	Post Lactate ($mmol \cdot l^{-1}$)	Δ Lactate (%)
Easy	10	3.5 (0.5)	3.3 (0.4)*	-2.3 (16.3)*
Easy	30	2.9 (0.7)	2.8 (0.2)*‡	0.7 (25.2)*
Moderate	10	3.2 (0.6)	3.1 (0.2)*	2.2 (19.0)*
Moderate	30	3.2 (0.4)	3.9 (0.3)	24.5 (17.1)†
Hard	10	2.7 (0.4)	6.2 (1.8)	146.3 (87.9)
Hard	30	2.8 (0.3)	5.4 (1.1)	91.6 (39.0)

* Different from training intensity Hard 10 minutes and 30 minutes ($p < 0.05$). † Different from training intensity Hard 10 minutes ($p < 0.05$). ‡ Different from training intensity Moderate 30minutes ($p < 0.05$).

resistance training), it is possible that differences in the number of familiarization sessions (1 vs. 20 in the present study) could explain the divergent results. Interestingly, the RPE values reported in the previous study were similar to the values observed in the hard sessions in the present study.

As session-RPE is collected some time after a training bout, a hard or easy exercise component during the final part of intermittent activities or trainings performed in intervals could compromise the accuracy of this method (Foster et al., 2001; Singh et al., 2007). Thus, given its intermittent nature, boxing training routines are an ideal candidate for such interference (Kravitz et al., 2003). However, the present findings suggest that the overall session-RPE was not compromised by exercise performed in the last part of our boxing routines, Shadowing (Simulated Fight) (Table 4), which in the hard session had a similar heart rate behavior to 'open' sparring in an international amateur boxer, values above 180 bpm during the 'open' sparring were registered (Smith, 2006). These results indicate that, in Olympic boxing, 10 minutes is enough time to avoid the influence of a specific part of the training session on the session. Also, a recent study from Hornsby et al. (2013) strengthened the idea of session RPE as a global training session measurement that is not influenced by the terminal part of training bout.

This observation has important implications, as the time demands for using the session-RPE method are reduced, further supporting the use of session-RPE as a practical method to quantify training load in athletes as opposed to more tedious objective measures which create obvious barriers.

In this study, the training activities (Table 4) were designed both to replicate the demands of boxing and to allow good control of the external loads applied. Indeed, both the HR and lactate data demonstrated that the exercise protocol was well controlled and the external loads were applied as intended (i.e. easy, moderate or hard). Moreover, the results obtained with the push-up performance test demonstrated that similar fatigue levels were experienced between the sessions from which the RPE's were taken at 10 and 30 minutes (Figure 1).

Previous studies have shown that boxing requires high intensity exercise (Siegler and Hirscher, 2010) and that RPE values increase during both boxing-specific exercises and during sparring bouts (Kravitz et al., 2003; Siegler and Hirscher, 2010). In agreement with these observations, our HR data show an increment in the intensity measurements from the beginning to the end of Olympic boxing routines (Table 2). Additionally, these results corroborate recent studies in soccer that have reported metabolic inertia and tendency to increase HR, blood lactate and RPE values during the 4 x 4 minutes interval soccer small-sided games (Coutts et al., 2009). Lastly, the present work showed mean HR values similar to those previously reported in 3 minutes sparring bouts in trained boxers (Siegler and Hirscher, 2010) and blood lactate values (i.e. 4-6 $mmol \cdot L^{-1}$) during 1 minute boxing bout rounds (Faina et al., 1990). Thus, further studies must be performed in order to reinforce that session-RPE can replace physiological objective measurements as markers of the stress induced by exercise and consequently that session-RPE is useful to quantify training load in boxing.

The TRIMP is the original HR-based measure of training load (Banister et al., 1975; Fitz-Clarke et al., 1991; Morton et al., 1990) and is commonly applied to monitor the training dose in many endurance sports (Borresen and Lambert, 2009). Despite its widespread use in endurance sports, HR-based TRIMP has been suggested to be limited in monitoring very high-intensity exercises (e.g. weight training, high-intensity interval training and plyometric training) (Foster et al., 2001). Nonetheless, the present study showed that the session-RPE measures followed the same pattern as the TRIMP measures, providing further evidence to support the validity of using session-RPE to quantify training load in boxing.

Conclusion

Here we show that session RPE is useful to quantify Olympic boxing training routines. We also show that post-exercise RPE can be collected as fast as 10 minutes after training session with no loss of measurement quality, in contrast to initial recommendations of collecting after 30 minutes. Data collected after 10 or 30 minutes are equally increased and directly correlate to training intensity.

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Key points

- It is difficult to quantify and monitoring the external training load in martial arts (e.g. Aikido, Kung Fu, Judo) and physical combat sports (e.g. Boxing, Muay Thai), session RPE method appears to be a reliable method to quantifying training load in those sports.
- For many athletes it is impractical to wait 30 minutes after training session to provide a session-RPE. The present findings show that collecting session-RPE measures at 10 min following exercise sessions of various intensities (i.e. easy, moderate, and hard) provide similar values as if taken 30 min following the session.
- Our data have significant practical benefit and further support the practical usefulness of session-RPE for measuring internal training load in sport.

AUTHORS BIOGRAPHY

Marco Carlos UCHIDA
Employment
Associate Professor, Faculty of Physical Education, State University of Campinas, Campinas, Brazil
Degrees
MSc, PhD
Research interests
Resistance training and muscle physiology
E-mail: uchida@fef.unicamp.br; uchidamc@gmail.com

Luis Felipe Milano TEIXEIRA
Employment
Lecturer, Faculty of Physical Education, UNIFIEO, Osasco, Brazil
Degree
MSc
Research interests
Sports training and sports nutrition
E-mail: teixeira.luisfelipe@gmail.com

Vladimir Juliano GODOI
Employment
Professional coach (LiSoBOXE); Lecturer, Faculty of Physical Education, Anhanguera Educational, Sorocaba, Brazil
Degree
MSc candidate
Research interests
Combat sports and sports training
E-mail: vladimir@lisoboxe.com.br

Paulo Henrique MARCHETTI
Employment
Associate Professor, Human Movement Sciences Graduate Program, School of Health Sciences, Methodist University of Piracicaba, Piracicaba, Brazil
Degrees
MSc, PhD
Research interests
Biomechanics and sports training
E-mail: dr.pmarchetti@gmail.com

Marcelo CONTE
Employment
Associate Professor, School of Physical Education of Jundiaí, Jundiaí, Brazil
Degrees
MSc, PhD
Research interests
Sports Medicine and Science
E-mail: contemarcelo@bol.com.br

Aaron James COUTTS
Employment
Professor, Faculty of Health, University of Technology Sydney, Sydney, Australia
Degrees
MSc, PhD
Research interests
Sports training, monitoring performance, fatigue and recovery in athletes
E-mail: aaron.coutts@uts.edu.au

Reury Frank Pereira BACURAU
Employment
Associate Professor, School of Arts, Sciences and Humanities, University of São Paulo, São Paulo, Brazil
Degrees
MSc, PhD
Research interests
Exercise and immune system and sports medicine
E-mail: reurybacurau@usp.br

✉ **Marco Carlos Uchida, MSc, PhD**
Faculty of Physical Education, State University of Campinas, Av. Érico Veríssimo, 701. Campinas, SP, Brazil - CEP: 13083-851