PHYSICAL PERFORMANCE, TIME-MOTION, TECHNICAL-TACTICAL ANALYSES, AND PERCEPTUAL RESPONSES IN BRAZILIAN JIU-JITSU MATCHES OF VARIED DURATION

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Abstract:

This study aimed to analyze performance, time structure, technical actions, and perceptual responses of Brazilian jiu-jitsu athletes during matches of varied duration. For this, 10 athletes were analyzed in matches of varied duration (2-min, 5-min, 8-min and 10-min). Physical tests (reaction time, maximal isometric handgrip strength, grip strength endurance, vertical jump and sit-and-reach) and perceptive scales (exertion and recovery) were applied before and immediately after a combat. The matches were recorded for technical-tactical analysis and to determine their time structure. The main results showed that alterations were observed for the grip strength with kimono (p=.001), whereas a decrease was observed in the suspension time in the 8-min (p=.017) and 10-min (p=.002) combats compared to pre-match mean values. The rating of perceived exertion was influenced by time (p<.001), with higher values reported after combats of 8-min and 10-min duration compared to 2-min combat (p=.008 and p=.001; respectively). The effort:pause ratio did not differ between the times of combats (p=.472), but the pause time differed according to match duration (p=.004), with higher values observed in the 10-min combats than in the 2-min combats (p=.002). Thus, it was concluded that combats of longer duration resulted in higher perceived exertion, higher pause time and lower strength endurance.

Key words: *combat sport, performance analysis, fatigue, strength endurance, isometric strength*

Introduction

In recent years, the number of studies investigating Brazilian jiu-jitsu has increased. However, these studies are not yet sufficient to accurately describe the combat demands. Indeed, the main focus of interest has been on the metabolic and hormonal responses (Andreato, et al., 2013, 2015a; Moreira, et al., 2012) and handgrip strength (Andreato, et al. 2013, 2014, 2015b).

Some studies have focused on metabolic response to analyze the effect of successive combats. A study of three simulated Brazilian jiu-jitsu combats (10 minutes each) concluded that successive Brazilian jiu-jitsu simulated combats demanded considerable anaerobic energy release, reinforcing the high-intensity intermittent nature of the sport. Nevertheless, no negative impact on acute neuromuscular performance (power) was observed (Silva, Ide, Moura Simim, Marocolo, & Mota, 2014a). In a simulated competition (four matches of 10 minutes each), successive matches induced a gradual decrease in adrenergic and glycolytic activities, accompanied by a gradual increase in cell damage markers and a decrease in the average of the normal R-R intervals of heart rate variability (Andreato, et al., 2015a) and in maximal isometric handgrip strength. However, no changes in the time structure of the matches or in perceptual responses were observed (Andreato, et al., 2015b).

In an analysis of 33 matches of the 2005 World Cup, Brazilian jiu-jitsu combats were characterized by more frequent scoring in the initial and final minutes (Del Vecchio, Bianchi, Hirata, & Chacon-Mikahili, 2007). This fact is interesting in light of the idea that the initial and final minutes of the combat tend to generate greater fatigue and exhibit a more intense temporal structure. However, little is known about this relationship.

Additionally, it is important to understand the time course of physical abilities during the match to improve training prescription and increase performance of specific aspects in the proper moment of the match. In this sense some variables have been considered relevant in grappling combat sports (Andreato, et al., 2015b; Barbas, et al., 2011; Kraemer, et al., 2001): reaction time, maximal isometric handgrip strength, upper-body strength endurance, lower-body muscle power, and flexibility. Reaction time has a direct implication for the reaction to the opponent's attacks, facilitating defensive actions or the application of counter-attacks. Handgrip strength and handgrip strength endurance are important because athletes perform the combat by gripping the opponent's kimono (e.g. gripping dispute, dominance over the opponent, application of techniques, etc.) (Vidal-Andreato, et al., 2011). Lower-body muscle power is relevant for the application of throwing techniques and for some specific movements of groundwork actions (sweeps and guard pass). Flexibility facilitates the application of techniques and is important for defensive actions in specific situations (e.g. berimbolo guard and spider guard) (Vidal-Andreato, et al., 2011).

Knowledge about the impact of different combat durations on physical performance can be valuable to Brazilian jiu-jitsu coaches, who can implement different durations of effort when focusing on different fatigue states and technical-tactical actions. However, only two studies (Franchini, Bezerra, Oliveira, Souza, & Oliveira, 2005; Franchini, Takito, & Pereira, 2003) investigated variations in performance throughout a Brazilian jiu-jitsu match. In one study the authors (Franchini, et al., 2003) reported that maximal isometric handgrip strength was maintained during a 5-min match simulation, while in the other (Franchini, et al., 2005) they observed a decrease in this variable from the fourth minute until the end of a 10-min Brazilian jiu-jitsu match. Moreover, the latter study reported that the rating of perceived exertion during the final minutes (the eight to tenth minute) was higher than that during the initial minutes (the second to fourth minute).

Thus, to date, no study has evaluated the effect of combat duration on performance tests other than handgrip strength or on the time structure of combats. This knowledge could significantly improve training for Brazilian jiu-jitsu athletes, particularly because Brazilian jiu-jitsu competitions adopt different match durations (e.g. the UEA Jiu-Jitsu Federation established 6-min matches for black belts, whereas the International Brazilian Jiu-Jitsu Federation established 10-min matches) (IBJJF, 2015; UEAJJF, 2015).

In view of the previously mentioned considerations, this study aimed to evaluate physical performance (via a test battery), perceptual responses, temporal performance and technical-tactical performance during Brazilian jiu-jitsu matches of varied duration. The present study hypothesized that handgrip strength and grip strength endurance would decrease over the course of the match and that more pauses would be noted in the final minutes of matches.

Methods

Study design

This study is characterized as a descriptive comparison and exploratory study. The experimental model is presented in Figure 1. The subjects were submitted to evaluations during matches of varied duration (two simulations per day) and physical tests were applied pre-match and after the 2-, 5-, 8-, and 10-min matches (post-match) to investigate physiological changes over time. In addition, the matches were recorded for a technical-tactical analysis. The order of the matches of varied durations was counterbalanced with a 60-min rest interval between matches to allow the measured parameters to return to baseline.

Between the pre-match test and the beginning of every match, athletes were allowed a 5-min interval for recovery; this time was also used as a warm-up period. The warm-up was self-selected; however, the athletes were requested to adhere to the same warm-up protocol before all matches. Athletes were not informed in advance about the duration of matches and were encouraged to engage in fighting as if the total duration was 10 minutes.

The matches were timed, and the time during pauses was not counted as match time, like during official competitions. Moreover, the match was not over in the event of submission to guarantee that all athletes would have the same match duration. Similar procedures have been adopted in studies with other grappling combat sports (Andreato, et al., 2015a, 2015b; Barbas, et al., 2011; Kraemer, et al., 2001). Although brown-belt athletes officially compete in 8-min matches, those from our study were adapted to this condition since they were preparing to graduate to black belt.

The athletes were divided and matched by body mass to avoid significant weight category differences between them (less than 10% difference in body mass between the athletes). Namely, in official competitions, athletes are classified into weight categories within this range of variation in body mass.

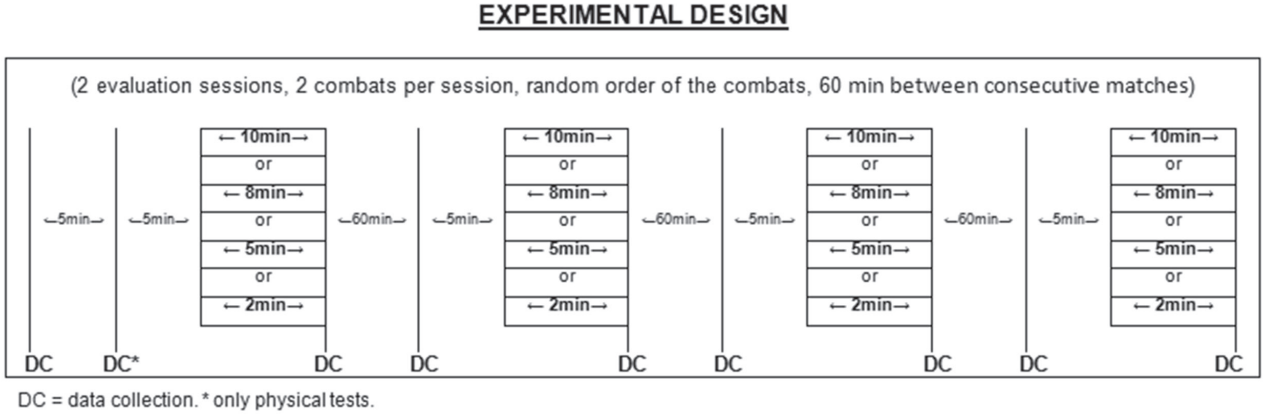

Figure 1. Experimental design – matches of varied duration.

Subjects

The study included 10 male adult Brazilian jiu-jitsu athletes (age: 29±5 years, body mass: 77.5±6.3 kg, body height: 177.1±8.0 cm, body fat: 10.0±5.2%), with 10±2 years of regular and systematic practice (six brown belts and four black belts). During the study, an injury occurred during one of the matches; however, the injury occurred at the end of the combat and did not affect the results obtained. Although we did not conduct a sample size calculation, due to the lack of baseline measurement, we assumed that this number of subjects was adequate, as it was similar to previous studies of Brazilian jiu-jitsu and wrestling (Andreato, et al., 2015a, 2015b; Barbas, et al., 2011; Kraemer, et al., 2001).

The following inclusion criteria were adopted: athletes graded brown-belts or black-belts (to ensure the experience of the subjects); Brazilian jiu-jitsu specific training at a minimum frequency of three times per week (typical duration of one hour and 30 minutes per session); and training for at least three months without any interruption. Exclusion criteria were: athletes with injuries, those in the ultra-heavyweight (>100 kg) category, those in the process of weight loss, and/or those using illicit (e.g. anabolic steroids and recreational drugs) or other drugs (e.g. antibiotics and anti-inflammatory drugs). Athletes who were using dietary supplements were advised to maintain constant use during the study. Additionally, the athletes were instructed not to perform any kind of physical activity 24 hours before data collection.

After being briefed on the procedures and purpose of the study, the participants signed a written and informed consent to participate. The study was carried out in accordance with the resolution 196/96 of the Brazilian National Health Council and approved by the Local Ethics Committee (2011/032).

Anthropometry

The measurement of skinfold thickness (chest, midaxillary, triceps, subcapular, abdominal, suprailiac and medial thigh) was performed in triplicate, and the average value was used, according to the standardisation method of Lohman, Roche, and Martorell (1988). Measurements were performed by an experienced evaluator. The technical error in the measurement of skinfold thickness was less than one millimeter, and the coefficient of variation was below 3% for all the measurements used in this study. From the skinfold thickness scores, body density was determined using the equation of Jackson and Pollock (1978), and percent body fat was estimated using the equation of Siri (1961).

Rating of Perceived Exertion and Perceived Recovery Status

The Borg 6-20 scale was used to measure the rating of perceived exertion (Borg, 1982). The participants were asked to make use of any number on the scale to classify their global effort. Latency or no exertion was indicated by 6, whereas 20 indicated maximum exertion. The rating of perceived localized fatigue was applied according to the proposal presented by Nilsson, Csergö, Gullstrand, Tveit, and Refsnes (2002). This scale model presents the athlete with an anterior and posterior anatomical map of human body, and the athlete was required to indicate muscle regions where most fatigue was felt. Thereafter, the athletes were asked to rate their perceived exertion at each referred point using the 6-20 scale (Borg, 1982). In addition, to assess the athletes' recovery status, the perceived recovery status scale (Laurent, et al., 2011) was administered before each match, with scores ranging from 0 (very poorly recovered/extremely tired) to 10 (recovered well/highly rested).

Physical tests

To measure reaction time, the athletes were instructed to remain upright and stable over a jump platform (Hidrofit®, Belo Horizonte, Brazil) controlled by MultiSprint® software (Hidrofit®, Belo Horizonte, Brazil). The athlete received a sound

stimulus – a beep – and had to react as rapidly as possible by performing a jump. Time between the sound and the mechanical response was defined as the reaction time (Kraemer, et al., 2001). To measure maximal isometric handgrip strength, the athletes performed the handgrip test (Johnson & Nelson, 1978) with a Jamar® dynamometer model J00105 (Lafayette Instrument®, Lafayette, USA) adjusted to hand size. Isometric strength endurance was evaluated by the maximum static suspension test gripping the kimono (Silva, et al., 2012). The athletes also performed the sit-and-reach test from Wells and Dillon (Johnson & Nelson, 1978). Finally, to measure the lower limb muscle power, a countermovement jump test on a jump platform was performed (Cronin & Hansen, 2005).

Before the first match, the athletes performed three non-sequential trials of each test. A 1-min interval between trials was established (Brown & Weir, 2001). In the remaining evaluations, two non-sequential trials were conducted with 1-min intervals for the pre-match testing and minimum (<10 seconds) intervals for the post-match evaluations. This design was adopted for the post-match evaluations to exclude any recovery time between the end of the match and the tests. This procedure was not applied to the maximum static suspension test gripping the kimono, given that it was performed only once for each test battery.

Additionally, to ensure the reproducibility of physical measurements, the athletes performed two test batteries before the first match with 5-min interval between them. This time interval was assumed to be the same amount of time that was available for the athletes as the interval between the pre-match test battery and the matches (see Figure 1).

The test and retest values for the batteries did not differ among themselves. Moreover, based on the intraclass correlation coefficients (ICC; model 2,1), satisfactory values were observed (ICC>.7) for the dominant handgrip (ICC:.72) and excellent values (ICC>.75) were observed for the variables of reaction time (ICC:.81), non-dominant handgrip (ICC:.97), vertical jump (ICC:.98), maximum static suspension test gripping the kimono (ICC:.93) and flexibility (ICC:.96) (Szklo & Nieto, 2000).

Technical-tactical analysis

The combats were recorded using a Sony digital camera, model DCR-SX40 (Sony®, Manaus, Brazil). The effort:pause ratio and the subjective intensity of the actions were categorized as low- and high-intensity. To define the effort:pause ratio, the period between the referee's commands to fight and to stop was defined as an effort, and the period between the orders to stop and to restart the fight was defined as a pause. The effort and pause periods were also quantified in each block of combat. These analyses were similar to that conducted previously in Brazilian jiu-jitsu (Andreato, et al., 2013, 2015b; Del Vecchio, et al., 2007).

To subjectively categorize intensity of workload (low- and high-intensity), a high-intensity action was identified when the fighter tried to advance/progress/evolve with clear vigor, muscle strength or power, whereas low-intensity actions were those for which movements were slow and a low level of strength appeared to be applied. Note that a tactical advance was not necessarily a high-intensity action, although it could be as effective as a vigorous action. These analyses were performed as defined previously for Brazilian jiu-jitsu matches (Andreato, et al., 2013, 2015b).

To quantify the number of effective motor actions, we considered the techniques that generated points or submissions; to quantify the number of non-effective motor actions, we considered the techniques that did not generate points or submissions. This quantification was performed using the method proposed by Andreato et al. (2015b).

Statistical analysis

The data are presented as means, standard deviations, percentages and delta (final value – initial value). Pre-match values were found to be similar using one-way analysis of variance (ANOVA) for repeated measures and followed by Bonferroni *post-hoc*. Therefore, the mean of all individual pre-match values was calculated and a one-way ANOVA for repeated measures was performed to compare the pre-match mean with the post-match values for matches of varied durations.

The analyses respected the assumption of sphericity assessed by Mauchly's test and utilized the Greenhouse-Geisser correction when necessary. Additionally, to evaluate the magnitude of difference, effect size was calculated (eta squared, η^2). Threshold values to effect size were <.2 (small), >.2 and <.8 (moderate) and >.8 (large) (Cohen, 1988). The significance level was set at 5%.

Results

Table 1 presents the results of physical tests before and after the Brazilian jiu-jitsu matches of varied duration.

No alterations (p>.05) were observed in the reaction time or maximal isometric handgrip strength of the dominant side. Differences were observed in maximal isometric handgrip strength of the non-dominant side ($F_{2,3;\,20,6}$=3.3, p=.049, η^2=.27, moderate), but the Bonferroni test did not confirm the differences.

Height of the countermovement jump did not differentiate (p>.05) among matches of different durations. Duration of the matches influenced grip endurance strength ($F_{4,36}$=5.6, p=.001, η^2=.38, moderate), with a decrease in the suspension time for the 8-min (p=.017) and 10-min matches (p=.002)

Table 1. Results of the physical tests before and after the Brazilian jiu-jitsu matches of varied duration (n=10)

	Pre-match	Post-match			
	Mean	2-min	5-min	8-min	10-min
Reaction time (s)	.48±.05	.45±.03	.47±.07	.47±.06	.47±.05
D-HG (kgf)	49±6	51±7	49±6	46±8	47±10
ND-HG (kgf)	47±6	48±8	47±7	45±8	42±9
CMJ (cm)	39±3	40±4	40±5	40±2	41±4
MSSTGK (s)*	30±13	27±11	25±12	23±12 [a]	21±8 [a]
Sit-and-reach (cm)	26±9	28±9	26±11	26±10	29±10

Data are presented as M±SD. *: n=9. D-HG: dominant handgrip, ND-HG: non-dominant handgrip, CMJ: countermovement jump, MSSTGK: maximum static suspension test gripping the kimono. [a] significantly different from the pre-match values (p<.05).

compared to the pre-match values. The analysis of variance demonstrated differences in the flexibility values ($F_{2,1;\ 19,1}$=3.8, p=.039, η^2=.29, moderate), but the Bonferroni test did not confirm the differences.

Table 2 presents the variation in the performance of athletes during matches of varied duration.

The delta analysis of the matches did not reveal differences (p>.05) in the reaction time, dominant or non-dominant handgrip strength, countermovement jump, grip strength endurance, or flexibility in the sit-and-reach test.

Table 3 presents the variation per minute in the performance responses of Brazilian jiu-jitsu athletes in matches of varied duration.

The variation per minute exhibited differences in the reaction time values ($F_{1,4;\ 12,5}$=6.5, p=.002, η^2=.42, moderate), but the Bonferroni test did not confirm the differences. No differences (p>.05) were observed for the dominant and non-dominant handgrip strength, countermovement jump, grip strength endurance, or flexibility in the sit-and-reach test.

Table 2. Variation (Δ) of the performance responses of athletes during matches of varied duration (n=10)

	Match 2-min	Match 5-min	Match 8-min	Match 10-min
Δ Reaction time (s)	-.04±.04	-.01±.04	.00±.06	.00±.05
Δ D-HG (kgf)	0±4	1±5	-2±3	-3±6
Δ ND-HG (kgf)	0±6	0±5	-1±4	-4±7
Δ CMJ (cm)	2±3	1±2	2±1	1±3
Δ MSSTGK (s) *	-4±7	-8±12	-3±7	-10±9
Δ Sit-and-reach (cm)	1±2	1±2	1±2	1±2

Data are presented as M±SD. *: n=9. D-HG: dominant handgrip, ND-HG: non-dominant handgrip, CMJ: countermovement jump, MSSTGK: maximum static suspension test gripping the kimono.

Table 3. Variation per minute (Δ / min) in the performance responses of Brazilian jiu-jitsu athletes in matches of varied duration (n=10)

	Match 2-min	Match 5-min	Match 8-min	Match 10-min
Δ / min Reaction time (s)	-.02±.02	.00±.01	.00±.01	.00±.00
Δ / min D-HG (kgf)	0±2	0±1	0±0	0±1
Δ / min ND-HG (kgf)	0±3	0±1	0±1	0±1
Δ / min CMJ (cm)	1±1	0±0	0±0	0±0
Δ / min MSSTGK (s) *	-2±3	-1±2	0±1	-1±1
Δ / min Sit-and-reach (cm)	1±1	0±0	0±0	0±0

Data are presented as M±SD. *: n=9. D-HG: dominant handgrip, ND-HG: non-dominant handgrip, CMJ: countermovement jump, MSSTGK: maximum static suspension test gripping the kimono.

Table 4 reports the time structure (effort and pause) of matches of varied duration.

No differences (p>.05) were observed regarding the number of effort blocks and efforts per block. The analysis of variance revealed differences in the total pause time ($F_{3,12}$=5.1, p=.017, η^2=.56, moderate), but the Bonferroni test did not confirm the differences. No differences (p>.05) were observed for the number of pause blocks. The pause time per block varied according to the match duration ($F_{3,12}$=5.2, p=.004, η^2=.90, large), with longer pauses in the 10-min matches than in the 2-min matches (p=.002). The effort:pause ratio did not differentiate (p>.05) among the different match durations.

Table 5 reports the time structure (high- and low-intensities) of matches of varied duration.

Differences were observed for the total time of high-intensity effort ($F_{3,12}$=16.5, p<.001, η^2=.81, large), with shorter durations of high-intensity effort observed in the 2-min matches than in the 10-min matches (p=.008). The number of high-intensity effort blocks also differentiated among the matches of various durations ($F_{3,12}$=49.7, p<.001, η^2=.93, large), with a greater number of high-intensity effort blocks in the 10-min matches than in the 2-min (p=.008) and 5-min matches (p=.015). The number of high-intensity blocks was higher in the 8-min matches than in 2-min (p=.002) and 5-min matches (p=.004). However, there was no difference (p>.05) in the time of high-intensity effort per block.

The total time of low-intensity effort differentiated between the matches of different durations ($F_{3,12}$=2331.7, p<.001, η^2=1.00, large), with a greater low-intensity time in the 10-min matches than in the 2-min, 5-min and 8-min matches (p<.001 for all comparisons). The low-intensity time in the 8-min matches was longer than in the 2-min and 5-min matches (p<.001 for the two comparisons), and the low-intensity time in the 5-min matches was longer than in the 2-min matches (p<.001). However, no differences (p>.05) were observed concerning the time of low-intensity effort per block or in the high-intensity:low-intensity ratio.

The number of attacks during matches of varied duration is presented in Table 6.

The analysis of variance revealed differences in the total number of effective attacks ($F_{1,7;\ 15,4}$=4.1, p=0.043, η^2=,31, moderate), but the Bonferroni test did not confirm the differences. The number of effective attacks per minute did not differ (p>.05) between the matches of different durations.

The total number of non-effective attacks differentiated between the matches of varied durations ($F_{3,27}$=35.6, p<.001, η^2=.70, moderate), with the 2-min matches characterized by fewer attacks than the 5-min (p=.016), 8-min (p<.001) and 10-min matches (p=.001), and the 5-min matches characterized by fewer attacks than the 8-min (p=.020) and 10-min matches (p=.030). However, no differences (p>.05) were observed concerning the number of attacks normalized to the duration of the match.

The rating of perceived exertion (2-min match: 12±2, 5-min match: 13±1, 8-min match: 14±2, 10-min match: 15±2) was influenced by time ($F_{3,27}$=8.8, p<.001, η^2=.49, moderate), with higher values observed after 8-min and 10-min matches

Table 4. Time structure (effort and pause) of the Brazilian jiu-jitsu matches of varied duration (n=20 matches)

	Effort			Pause			E:P
	Total (s)	Blocks	Effort per block (s)	Total (s)	Blocks	Pause per block (s)	
2-min match	120±0	2±1	92±39	7±1	1±1	4±6	6:1
5-min match	300±0	2±1	160±82	32±19	1±1	25±19	5:1
8-min match	480±0	3±1	152±52	71±52	2±1	26±15	10:1
10-min match	600±0	3±1	214±84	69±40	2±1	33±8 [a]	7:1

Data are presented as M±SD, except the effort:pause ratio (E:P), which reflects the effort per block divided by pause per block. [a] Significantly different from the 2-min match (p<.05).

Table 5. Time structure (high- and low-intensities) of the Brazilian jiu-jitsu matches of varied duration (n=20 matches)

	High-intensity			Low-intensity			HI:LI
	Total (s)	Blocks	Per block (s)	Total (s)	Blocks	Per block (s)	Average
2-min match	10±4	4±1	3±1	110±4	5±1	23±8	1:10
5-min match	27±4	9±2	3±1	273±7 [a]	10±2	29±5	1:9
8-min match	41±13	15±1 [a b]	3±1	436±20 [a b]	17±2	26±3	1:10
10-min match	47±8 [a]	16±3 [a b]	3±0	553±8 [a b c]	17±2	33±5	1:11

Data are presented as M±SD, except the high-intensity:low-intensity ratio (HI:LI), which reflects the average high-intensity effort time divided by the average low-intensity effort time. [a] Significantly different from the 2-min matches (p<0.05), [b] Significantly different from the 5-min matches (p<.05), [c] Significantly different from the 8-min matches (p<.05).

Table 6. The number of effective attacks and non-effective attacks during Brazilian jiu-jitsu matches of varied duration (n=10)

	Match 2-min	Match 5-min	Match 8-min	Match 10-min
Effective attacks	.6±.5	1.2±1.0	2.5±2.3	2.3±.7
Effective attacks (action/min)	.3±.3	.2±.2	.3±.3	.2±.3
Non-effective attacks	1.0±.8	2.4±1.1 [a]	4.3±1.6 [a b]	5.2±2.4 [a b]
Non-effective attacks (action/min)	.5±.4	.5±.2	.5±.2	.5±.2

Data are presented as M±SD. [a] Significantly different from the 2-min matches (p<.05), [b] Significantly different from the 5-min matches (p<.05).

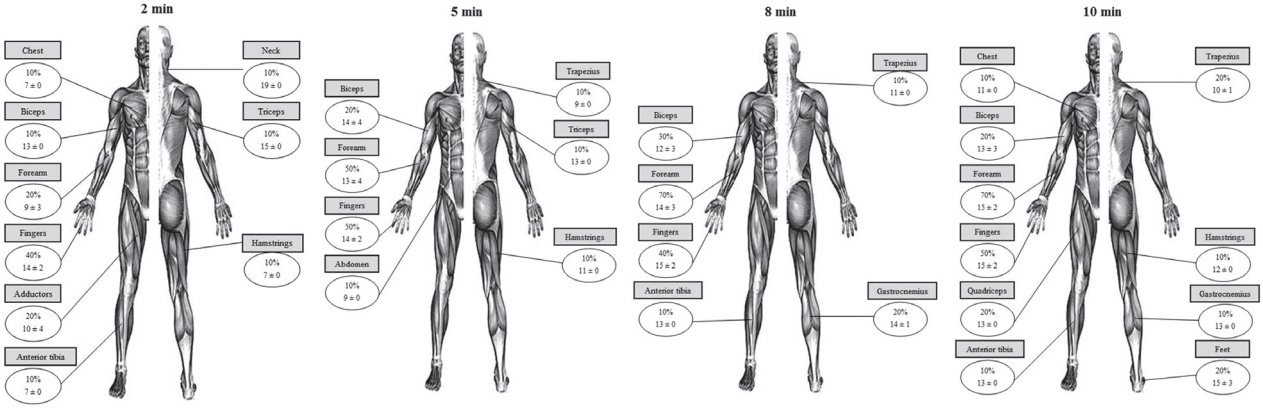

Figure 2. Perception of localized fatigue during Brazilian jiu-jitsu matches of varied duration (n=10).

than after 2-min matches. The athletes began every match without any differences (p>.05) in the perceived recovery status (8±1 for all matches).

Figure 2 presents characteristics of the perception of localized fatigue during matches of varied duration.

After 2-min matches, the athletes indicated 14 reports of fatigue in nine areas (chest, biceps, forearm, fingers**,** adductors, anterior tibia, neck, triceps and hamstrings). After 5-min matches, there were 16 reports of fatigue in seven areas (biceps, forearm, fingers**,** abdomen, trapezius, triceps and hamstrings). After the 8-min matches, 18 reports of fatigue were indicated in six areas (biceps, forearm, fingers, anterior tibia, trapezius, and gastrocnemius). After 10-min matches, 24 reports of fatigue over 10 areas were reported (chest, biceps, forearm, fingers**,** quadriceps, anterior tibia, trapezius, hamstrings, gastrocnemius, and feet).

Fatigue per match for each athlete altered during matches of varied duration ($F_{3,27}$=3.0; p=.049; η^2=.25, moderate), with a higher number of reports after the 10-min matches compared to the 2-min matches (p=.041). The athletes averaged 1±1 report, 2±1 reports, 2±1 reports, and 2±2 reports for the 2-min, 5-min, 8-min, and 10-min matches, respectively. The analysis of variance indicated a difference in the number of reports of fatigue per minute of a match ($F_{1,5;\ 13,2}$=6.0, p=.020, η^2=.40, moderate), but the difference was not confirmed by the Bonferroni test. The athletes indicated an average of 0.7±0.6, 0.3±0.3, 0.2±0.2, and 0.2±0.2 reports per minute for the 2-min, 5-min, 8-min, and 10-min matches, respectively.

Discussion and conclusions

This study aimed to evaluate performance, perception and temporal structure of Brazilian jiu-jitsu matches of varied duration. For this, two matches were performed per day, with a long test interval between matches so that each match was initiated without the influence of residual fatigue. This design was successful as there was no difference between the pre-match measurements for any variable. Moreover, the perceived recovery status prior to each match was constant. The present study demonstrated that matches of varied duration did not induce differences in physical performance. Longer effort and pause times were noted in longer matches. Concomitantly, the athletes' perceived exertion was greater in longer matches.

Physical performance is quite relevant for a demanding combat sport like Brazilian jiu-jitsu. In the present study, the reaction time was unchanged. These results are similar to those reported during simulated wrestling competitions, in which no increases in the reaction time were observed; on the contrary, the reaction time was optimized after some wrestling matches (Kraemer, et al., 2001).

The jump height was unchanged after all the matches. In a previous study, three Brazilian jiu-jitsu matches resulted in increased post-match values (pre-combat: 41±6 cm vs. post-combat: 42±6 cm) (Silva, et al., 2014a), which may suggest an effect of post-activation potentiation. A similar effect for countermovement jump values was observed in Brazilian jiu-jitsu simulated competitions (Andreato, et al., 2015b). However, in official combats during the 2013 European Open Jiu-Jitsu Championship a decrease was observed in maximal countermovement jump height (pre: 34.0±5.2 cm, post: 30.8±6.7 cm) (Diaz-Lara, Coso, García, & Vicén, 2015). In studies involving judokas, muscular power of the lower limbs was unaffected by matches (Bonitch-Domínguez, Bonitch-Góngora, Padial, & Feriche, 2010; Fernández, Soler, & Calvo, 2008), whereas, in wrestling, decreases in muscle power of the lower limbs were observed only after four matches (Barbas, et al., 2011; Kraemer, et al., 2001). Thus, in general, the lower limbs in Brazilian jiu-jitsu do not appear to be overloaded. This suggestion can be confirmed by the low reports of local fatigue for this region (Andreato, et al., 2014; Franchini, et al., 2005).

Maximal isometric handgrip strength has been evaluated in various studies of Brazilian jiu-jitsu (Andreato, et al., 2013; Franchini, et al., 2003, 2005). In the present study, the dominant and non-dominant handgrip strength was unchanged for all matches, regardless of their duration. These results differ from those observed in competitions at the regional level, in which athletes (n=35) exhibited a decrease in handgrip strength for both sides (Andreato, et al., 2013). However, in other regional competitions, decreases in handgrip strength of the dominant hand were observed, but no change in strength of the non-dominant hand was noted (Andreato, et al., 2014). Additionally, maximal handgrip strength was not influenced by match duration. The behavior of handgrip confirms previous studies with fragmented 5-min Brazilian jiu-jitsu matches in which no changes were found for different durations of combat (Franchini, et al., 2003). However, these responses differ from a study analyzing black-belt Brazilian jiu-jitsu athletes (n=8) who performed 10-min matches and underwent handgrip evaluations every two minutes, where maximal handgrip strength began to decrease in the fourth minute and stayed significantly lower than at rest until the end of the match (Franchini, et al., 2005).

Grip endurance strength was also unaffected by match duration as the post-match values did not vary. However, after longer matches (8-min and 10-min), the suspension time values were lower than the pre-match values. Grip strength endurance has been suggested to be an important indicator of Brazilian jiu-jitsu performance; in matches characterized by a decrease in maximal handgrip strength, athletes exhibited 89% (right hand) and 84% (left hand) of maximal handgrip strength after combats (Andreato, et al., 2013). This decrease occurred likely because matches involved constant gripping of the kimono. In addition, the forearm is the principal point for local fatigue reported after simulations (Franchini, et al., 2005) and after official matches (Andreato, et al., 2014). Moreover, no differences in maximal handgrip strength were noted, between experienced athletes and beginners, whereas differences in the grip strength endurance test were found, with higher performance for the experienced athletes (Silva, et al., 2014b).

Flexibility plays an important role during matches, especially for the application of technical actions and defensive maneuvers (Vidal-Andreato, et al., 2011). Flexibility, evaluated by the sit-and-reach test, did not change in any of the evaluated durations. These results may be associated with the fact that relatively low levels of lower limb fatigue have been reported after Brazilian jiu-jitsu matches (Andreato, et al., 2015b; Franchini, et al., 2005), and it is believed that one of the factors that may cause reduction of flexibility post-exercise is neuromuscular fatigue (Gleim & McHugh, 1997).

When analyzing the temporal structure of matches of varied duration, a progressive increase was observed in the total times and number of high- and low-intensity action blocks. However, these increases were expected since they reflected the difference in duration of matches. When the variables were analyzed after normalizing for combat duration (relative times to total time), longer effort and pause times per block were observed in the longer matches. These results differ from those observed in judo matches, in which shorter efforts and longer pauses were observed during the last minute of combats, a fact that can be attributed to fatigue (Franchini, Artioli, & Brito, 2013). In the present study, although there was an increase in the pause time per block, there was also an increase in the effort time per block in the longer matches.

The time structure of matches of varied duration oscillated between 83±37 and 230±63 seconds of effort and 5±6 and 35±6 seconds of pause. These values do not differ significantly from those reported previously in competitions at the regional level (117 seconds of effort by 33 seconds of pause) (Andreato, et al., 2013). Moreover, when the effort time was subdivided according to high and low intensities, a structure of high-intensity actions of around three seconds was interspersed by low-intensity actions of ~30 seconds. These findings confirm those obtained in regional competitions, in which blocks of approximately three seconds of high-intensity effort were interspersed by blocks of approximately 25 seconds of low-intensity actions

(Andreato, et al., 2013). These results concerning the temporality of combats have important implications for the organization of training. Knowledge of temporal characteristics should be used as the basis for proposing training sessions or exercises similar to the efforts made during combats (Franchini, et al., 2013).

In addition to the temporal structure, the number of effective and non-effective attacks varied concerning the total value, with a progression in the number of non-effective attacks. However, no differences were observed between the matches of varied duration when the number of attacks per minute was analyzed. This result can be used to control tactical training, in which athletes should be encouraged to maintain the same standard of combat pace.

Rating of perceived exertion was influenced by match duration, with higher values after longer matches. The present results are similar to those obtained in research involving Brazilian jiu-jitsu black-belt athletes (n=8) who engaged in 10-min matches and reported perceived exertion every two minutes, with the ratings of perceived exertion during the final minutes (the eighth and tenth minute) being higher than in the initial minutes (the second and fourth minute) (Franchini, et al., 2005). In the present study, the values obtained between the matches varied between 12 ("light") and 15 ("hard") on the scale from 6 to 20. These results are consistent with previous studies (Franchini, et al., 2005; Andreato, et al., 2012, 2013, 2015b). Andreato et al. (2012) found that their athletes reported 12 ("light") after 7-min match simulations, while in the study by Franchini et al. (2005) athletes reported 13 ("somewhat hard") after 10-min simulations. When analyzing four 10-min matches simulating a competition, athletes reported 16, 16, 15 and 16 ("hard"), respectively (Andreato et al., 2015b). In the study that investigated regional competition Andreato et al. (2013) found that athletes reported 15 ("hard") after the matches.

The results of rating of perceived exertion were not elevated, and it is necessary to note that rating of perceived exertion can be affected by physiological and psychological factors, just as the increase of external sensory stimuli (decision-making and sonorous stimulus, amongst others) can diminish the sense of exertion (Bridge, Jones, & Drust, 2009; Haddad, et al., 2011). During a combat athletes process a large amount of visual (gripping dispute), auditory (technical-tactical orientations provided by the coach), proprioceptive (exchanges of attempts to disturb balance) and kinaesthetic data (positions of different body parts) (Branco, et al., 2013). In addition, the alternation of muscular groups can distort the relationship between exercise intensity and the rate of perceived exertion experienced by these athletes (Andreato, et al., 2014).

The number of reports of local fatigue given by athletes was influenced by the match duration, with a higher number of reports after longer matches. Additionally, the most common areas of fatigue were the fingers and forearm. These findings are similar to previous results indicating that the forearm was the primary muscle group reported in 10-min simulations (Franchini, et al., 2005) and matches of regional competitions (Andreato, et al., 2014). Therefore, it is clear that the perceptive changes resulting from the matches are insufficient to trigger important changes in performance and in the structure of matches.

This study analyzed a relatively small sample of advanced (brown and black belt) athletes; beginners (white, blue and purple belt) athletes may show different responses, especially because the duration of combats is shorter for lower belt levels. The competitive level in the current investigation was varied, involving regional to international level athletes. Studies considering sex, age, weight and belt level must be carried out to improve knowledge in this modality.

Based on the results obtained in this study some practical application can be indicated. Rating of perceived exertion should be viewed with caution if used as a criterion for controlling intensity of Brazilian jiu-jitsu matches, as muscle group recruitment during a match and the focus of athlete's attention on the actions of his/her opponent can change the relationship between exercise intensity and the athlete's rating of perceived exertion (Andreato, et al., 2015b).

Furthermore, the perception of local effort should be used to prescribe resistance training focusing on the development of strength endurance in muscle groups involved in grip actions. In particular, the athletes exhibited a reduction in handgrip endurance after a combat, indicating a need for exercises aiming to increase muscular endurance in regions such as the forearm, where the athletes indicated a greater perception of fatigue.

In addition, no differences were observed among the matches of different durations, and the high-intensity actions lasted approximately 3 seconds, resulting in a high/low intensity ratio of 1:10. Therefore, this time structure can be used to prescribe both physical and technical-tactical training programs.

In summary, different match durations resulted in distinct perceptual responses. In the longer matches, greater rating of perceived exertion, longer pause time and lower strength endurance (evaluated by maximum static suspension test gripping the kimono) were noted.

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Conflict of interest

The authors do not have any conflict of interest to report.