Effects of a Brazilian jiu-jitsu training session on physiological, biochemical, hormonal and perceptive responses

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B Data Collection
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Abstract

Background & Study Aim: Brazilian jiu-jitsu (BJJ) training consists of actions performed from vertical posture (throws) and from ground positions (groundwork), including strangulation, joint lock techniques (wrist, arm, ankle, knee and leg), knee on belly, and immobilisation manoeuvres There were two objectives of these studies: the effect of a Brazilian jiu-jitsu training session on physiological, biochemical, hormonal, and perceptive responses: the rating of perceived exertion (RPE) in relation to physiological effects, cellular damage, and hormone levels generated by training.

Material & Methods: Fourteen male-adult Brazilian jiu-jitsu athletes participated in a training session lasting 1h30min and consisting of six matches. Before, immediately after, and post 24h, venous blood samples were collected to measure cellular damage and hormonal levels. During the training, blood lactate (La), heart rate (HR), the RPE (6-20 scale for matches and 0-10 scale, thirty minutes after session), and local fatigue were measured.

Results: Results showed that the levels of cortisol, testosterone/cortisol ratio, creatine kinase (CK), aspartate (AST) and alanine (ALT) aminotransferase remained high at least until post 24h ($p<0.01$). There was a post-training increase of lactate dehydrogenase (LDH) ($p<0.001$), but this returned to baseline post 24h. By the fourth match correlations were observable between (La) and HR ($r = 0.48$; $p<0.05$) and between RPE_{6-20} and HR ($r = 0.66$; $p<0.01$). Also, observed immediately after training was a correlation between the internal training load and delta of ALT ($r = 0.66$; $p<0.01$) and LDH ($r = 0.50$; $p<0.01$).

Conclusions: This type of training increases the catabolic state and generates cell damage that fails to return to basal levels even post 24h. The study also found that RPE_{6-20} is not very effective for predicting intensity throughout the training (matches performed), which suggests that perceptive scales should be used with caution.

Keywords: cellular damage • combat sports • matches performed • training control • training load

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Brazilian jiu-jitsu – is a type of fight in which a uniform or gi is used; its main purpose is to project or take your opponent down. Once on the ground, you must seek to control your adversary with different techniques (immobilizations, chokes, joints locks). In the absence of submission at the end of the fight, the winner is declared by the number of points won [36].

Judogi – is the formal Japanese name for the traditional uniform used for judo practice and competition [37].

Combat sport – *noun* a sport in which one person fights another, e.g. wrestling, boxing and the martial arts [38].

Randori – sparring in judo in which both participants practice attacking and defending [39].

Rating of perceived exertion – scale used to measure the intensity of effort exerted.

Cellular damage – this occurs when there is a rupture of the intercellular muscular structure, sarcolemma and intracellular matrix, causing an insufficiency in muscular activity.

Rating – position on level given to something in comparison to others.

Internal training load (ITL) – the internal effect on an organism as a result of training.

Ukemi – the term for break falls designed to process the body when thrown [39].

Training load – "A simple mathematical model of training load can be defined as the product of qualitative and quantitative factor. This reasoning may became unclear whenever the quantitative factor is called 'workload volume' or 'training volume' interchangeably with 'volume of physical activity'. Various units have been adopted as measures i.e. the number of repetitions, kilometres, tons, kilocalories, etc. as well as various units of time (seconds, minutes, hours) (…) As in the real world nothing happens beyond the time, the basic procedure of improvement of workload measurement should logically start with separation of the time factor from the set of phenomena so far classified together as '*workload volume*'. (…) Due to the fact that the heart rate (HR) is commonly accepted

Introduction

Brazilian jiu-jitsu (BJJ) training consists of actions performed from vertical posture (throws) and from ground positions (groundwork), including strangulation, joint lock techniques (wrist, arm, ankle, knee and leg), knee on belly, and immobilisation manoeuvres [1]. Intermittence is one of the main characteristics of matches, which require specific high and low intensity actions, all of which generate a high metabolic and physical demand [1, 2]. Because of the high level of physical preparation needed to endure these demands, the athletes need to train frequently [3, 4]; the more so due to the dense schedule of BJJ competitions throughout the year [5]. High-intensity exercises performed during athletes' frequent training sessions can cause muscle damage, where the magnitude of cell damage is directly related to the type, intensity, and duration of exercise as well as the training level of the athletes [6, 7]. Achieving ideal controls on the training process is therefore important for the development of competitive performance, as is achieving an ideal balance of training loads (**volume** and intensity[1]), both of which may be obtained by means of perceptive scales [8-10].

It is crucial that BJJ training sessions reproduce the demands of competitive matches because adaptations are specific to the training [11]. Because BJJ training is so intensive, it can be difficult for the researcher to intervene to measure glycolytic and cardiovascular demand without fundamentally disrupting the training routine [12]. For this reason, some studies of grappling combat sports have proposed the use of perceptive scales in order to obtain indirect indicators for estimating the glycolytic, cardiovascular, and fatigue demand. This has been done through the rating of perceived exertion (RPE), which has been measured in training [13] as well as in tournament competitions [4, 14, 15].

Branco et al. [13] incorporated perceptive scales in their study of judo, in which they observed very low positive correlations between delta of heart rate (HR), blood lactate concentration (La) and the rating of perceived exertion following a session using a 0-10 scale (RPE_{0-10}). RPE_{0-10} was therefore unable to predict accurately the glycolytic and cardiovascular demand after the *randori* (fight during the training). Serrano et al. [14], however, showed a positive correlation between (La) delta and RPE using a Borg 6-20 scale (RPE_{6-20}) during an official judo competition. Similarly, Bonitch et al. [15] observed positive correlations (r = 0.88) between HR and RPE_{6-20} during an official judo competition (tournament competitions). Findings like these can assist technical team in quantifying the required glycolic and cardiovascular demand during tournament competitions and, beyond that, establish which reliable and accessible tools can be used to monitor judo athletes during training and competitions.

Studies that have investigated the association between $RPE_{6–20}$, (La) and HR in BJJ training are still only very few [12]. Little is known about the physiological responses to BJJ training sessions beyond that a typical training session increases cellular damage markers: creatine kinase (CK) and lactate dehydrogenase (LDH) [3]. A deeper understanding of the demands of training sessions could aid greatly in the planning of those sessions, as it could assist technical team in quantifying the training load. An understanding of hormonal responses during BJJ training will, moreover, be indispensable in helping control anabolic/catabolic activity in order to prevent conditions associated with overtraining [16].

There were two objectives of these studies: the effect of a Brazilian jiu-jitsu training session on physiological, biochemical, hormonal, and perceptive responses: the rating of perceived exertion (RPE) in relation to physiological effects, cellular damage, and hormone levels generated by training.

It was hypothesised that cellular damage markers and hormone levels would increase immediately after training and remain increased for at least 24h after training. It was also hypothesised that RPE_{6-20} can predict the intensity of the glycolytic pathway and cardiovascular activation between training session matches.

Material and methods

Experimental approach to the problem

This study was based on a repeated measures design, in which the physiological, hormonal, biochemical and perceptive responses were evaluated during a BJJ training session. The training session lasted for 1h30min. Before the training session, while the athletes were at rest, researchers took blood samples from the antecubital veins (15 mL, to measure cellular damage markers and hormonal levels) and the ear lobe (25 µL, for blood lactate) and measured HR

1. See in glossary the term "training load" and concerning it recommendation of the paper which is raising a lot of controversies concerning the terminology, the measurement and documenting of training load.

by means of a cardiac monitor. Rating of perceived recovery (RPR; 0-10 scale) was also recorded for each athlete before the session began and 24h after training. The training session included 30 minutes of warm-up, which consisted of running, plyometrics, falling techniques (in judo this is known as *ukemi*), and drill exercises. Training then continued with athletes engaging in 6 matches, each 6 minutes in length and separated by four-minute intervals of passive rest the standard times for matches and rests in BJJ training). The athletes were asked to exert themselves maximally in each match, just as if they had been performing in a competition.

After each match, blood lactate was collected from the earlobe and HR and $RPE_{6\text{-}20}$ were measured. Athletes also indicated to the researchers their local fatigue by means of an anatomical map [17]. At the end of the training session, blood samples (15 mL) were taken from the antecubital veins in order to measure cellular damage markers and hormonal levels. 30 min after training, the athletes were asked to $RPE_{0\text{-}10}$, in order to identify the intensity of the training session. Moreover, 24h after the training ("post-24h training"), blood samples were again collected to measure cellular damage markers and hormonal concentrations; the athletes were also questioned once more about RPR. Figure 1 depicts the experimental design of this study.

Participants

Fourteen male adult BJJ athletes (aged: 27.8 ±6.1 years; body mass: 83.8 ±10.7 kg; stature: 179.7 ±3.8 cm) each with 8.3 ±3.1 years of regular and systematic BJJ practice (6 blue belts, 3 purple belts, 3 brown belts and 2 black belts) participated in the study. The following inclusion criteria were used: ≥3 years of regular and systematic practice of BJJ; participation in official competitions in the six months prior to the study; and participation in at least ≥3 specific BJJ training sessions per week (typical BJJ training sessions of approximately 1h30min). Athletes who used substances prohibited by the World Anti-Doping Agency [18] were excluded (athletes self-reported

as the universal measure of workload intensity, the product of effort duration and HR seems to be the general indicator of *training load* defined as the amount of workload. It is useful in analyses with a high level of generality. (…) In current research and training practice the product of effort duration and HR was referred to as conventional units' or further calculations have been made to convert it into points." [35, p. 238].

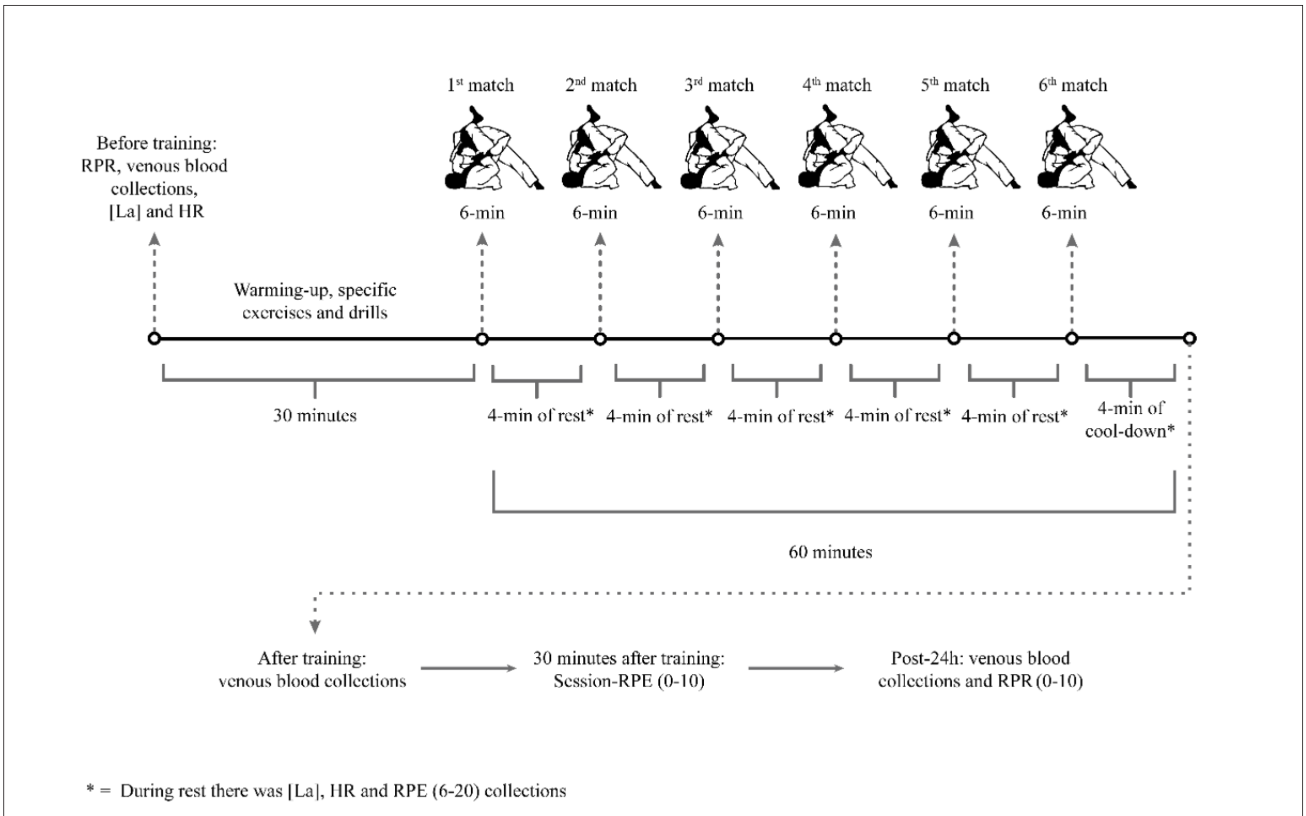

Figure 1. Experimental design.

Note: RPR rating of perceived recovery; **La** blood lactate; **HR** heart rate; **RPE** rating of perceived exertion (Borg 6-20); **RPE** (0-10) rating of perceived exertion (session-RPE 0-10 scale).

any use of prohibited substances via a questionnaire). Athletes who had been injured and were in the process of weight loss were also excluded (also determined by questionnaire). Participants were instructed not to take dietary supplements before, during, and post-24h training. The athletes were also instructed to refrain from any type of exertion 48h before the training. After being completely informed about the nature of the study, the participants signed a consent form. The study was approved by Hospital Celso Ramos and State University of Santa Catarina, Florianopolis, Santa Catarina, Brazil under number 4530021.1.00005360 and was found to abide by the recommendations of the Helsinki agreement.

Blood samples and biochemical analysis

Blood samples (15 mL) were collected from the antecubital veins at pre-, post- and post 24h training, in accordance with Figure 1. Blood was taken using Injex® 20 mL syringes (Ourinhos, Brazil) and BD Vacutainer® (Franklin Lates, United States of America) type Scalp 21 G disposable needles. Immediately after collection, 4 mL of each sample was put into Petrodis® (Sao Paulo, Brazil) 4 mL tubes with ethylene diamine tetra acetic acid (EDTA) in order to obtain the plasma. The remainder of each sample was deposited in glass tubes without anticoagulant for serum extraction. Each pair of tubes, one with and one without anticoagulant, were centrifuged at 3.500 rpm for 15 minutes at 4°C, for separation into plasma and serum. The samples were analysed immediately after centrifugation. To measure hormonal action in the plasma, an enzyme-linked immunosorbent assay (ELISA) was used to determine the cortisol and total testosterone levels with the use of Arbor® (Michigan, United States of America) commercial kits. For cell damage markers, LDH and CK in the serum were measured using the kinetic method. Alanine and aspartate aminotransferase (ALT and AST) concentrations were also measured in the serum using the colorimetric method. The analyses were performed using the Gold Analisa® (Belo Horizonte, Brazil) commercial kit, means by of Bioplus® UV-2000 (Sao Paulo, Brazil) spectrophotometer.

To measure La, blood samples (25 µL) were collected from the earlobe using heparinised capillaries and were stored in *eppendorf* microtubules containing 50 µL of sodium fluoride at 1% concentration and analysed after collection with a Yellow Springs YSI 1500® *lactimeter* (Ohio, United States of America).

Heart rate responses

HR was measured with the Polar® FT7 (Kempele, Finland) cardiac monitor. HR measurements were made immediately after the matches, with the cardiac monitor placed on the chest of the athletes.

Perceived responses

After each match the athletes were questioned about RPE for specific body parts (e.g., arms, forearms, thighs and legs: front and back, trunk, abdomen, and neck) using a posterior and anterior anatomical map of the human body, according to the method proposed by Nilsson et al. [17]. Athletes were also questioned about RPE in each report of fatigue, based on the 6-20 scale, expressed in arbitrary units (a.u.) [19]. Besides that, the RPE_{6-20} was used to quantify the intensity of each match during the training [19]. RPE for the entire session ("session-RPE") was recorded 30 min after the training session had ended, using a 0-10 scale a.u. In order to quantify the internal training load (ITL) scale a.u., session-RPE was multiplied by time of training session in minutes [20].

Athletes were also questioned about RPR both before the session and post-24h training. In order to verify RPR, the scale proposed by Laurent et al. [21] was used, with scores ranging from 0 (very poorly recovered/extremely tired) to 10 (recovered well/highly rested).

Statistical analysis

The data are presented as the mean and standard deviation (±). Homogeneity was previously tested by the Levene test. To compare the different moments, an one-way analysis of variance (ANOVA) with repeated measurements was used, followed by a Bonferroni test when necessary. The Mauchly test was applied to the data and verified that the assumption of sphericity was fulfilled. The Greenhouse-Geisser correction was applied when necessary. To compare the results of RPR from pre- and post-24h training, the paired student t-test was used. Since all data showed normality, Pearson's correlation of (La), HR and $RPE_{6–20}$ was used in order to verify possible associations between these variables throughout matches. Pearson's correlation was also used to verify possible associations between RPE_{0-10} and ITL in comparison to hormone levels and cellular damage markers. The significance level was set at 5% for all tests. To classify the magnitude of the correlations the method of Hopkins et al. [22] was used, and the following classifications were arrived at: <0.1 (trivial), ≥0.1 to 0.3 (small), >0.3 to 0.5 (moderate), >0.5 to 0.7 (large), >0.7 to 0.9 (very large) and >0.9 to 1.0 (almost perfect). Cohen *d* was calculated according to Rhea [23] for highly trained athletes: <0.25 (trivial); ≥0.25 to <0.5 (small); ≥0.5 to <1.00 (moderate) and ≥1.00 (large) whenever statistical differences were found. The data were analysed with SPSS version 20.0 (IBM, US) and Statistica software version 12.0 (Stasoft, US).

Results

For HR, there was a time effect ($F_{6,78} = 178.4$; $p<0.001$), with lower values for measures at rest when compared to post-first (d = 8.8, large), post-second (d = 9.2, large), post-third (d = 9.6, large), post-fourth

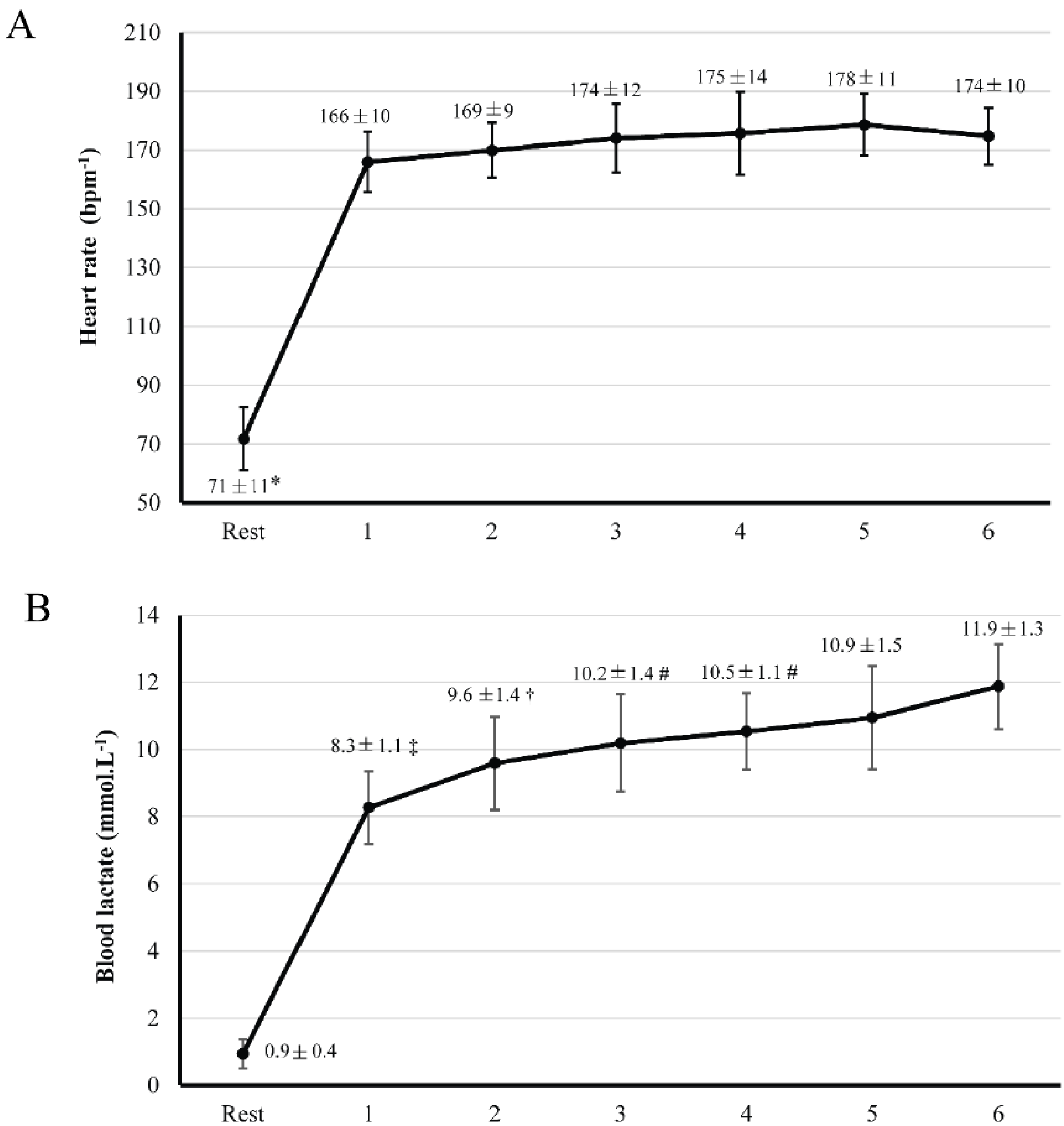

Figure 2. La and HR responses during BJJ training.

Note: data expressed as mean and standard deviation; **A** heart rate; **B** blood lactate; *different for all post-matches values ($p < 0.001$); ‡ different for post-third, fourth, fifth and sixth matches ($p<0.01$); †different for post-fifth and sixth matches ($p < 0.01$); # different for post-sixth match ($p<0.05$).

(d = 9.7, large), post-fifth (d = 10.0, large), and post-sixth (d = 9.6, large) matches ($p<0.001$; for all comparisons) (Figure 2).

For La, there was a time effect ($F_{6,76} = 190.6$; $p<0.001$), with lower values for measures at rest when compared to post-first (d = 17.0, large), post-second (d = 20.1, large), post-third (d = 21.5, large), post-fourth (d = 22.3, large), post-fifth (d = 23.2, large), and post-sixth (d = 25.4, large) matches ($p<0.001$; for all comparisons). Furthermore, the La post-first was lower when compared to post-third (d = 1.8, large), post-fourth (d = 2.1, large), post-fifth (d = 2.5, large), and post-sixth (d = 3.3, large) matches ($p<0.01$; for all comparisons). Similarly, the values for post-second were lower when compared to post-fifth (d = 1.0, large) and post-sixth (d = 1.6, large) matches ($p<0.01$; for both comparisons). Moreover, the post-third (d = 1.2, large) and post-fourth (d = 1.2, large) were lower when compared to post-sixth matches ($p<0.05$; for both comparisons) (Figure 2).

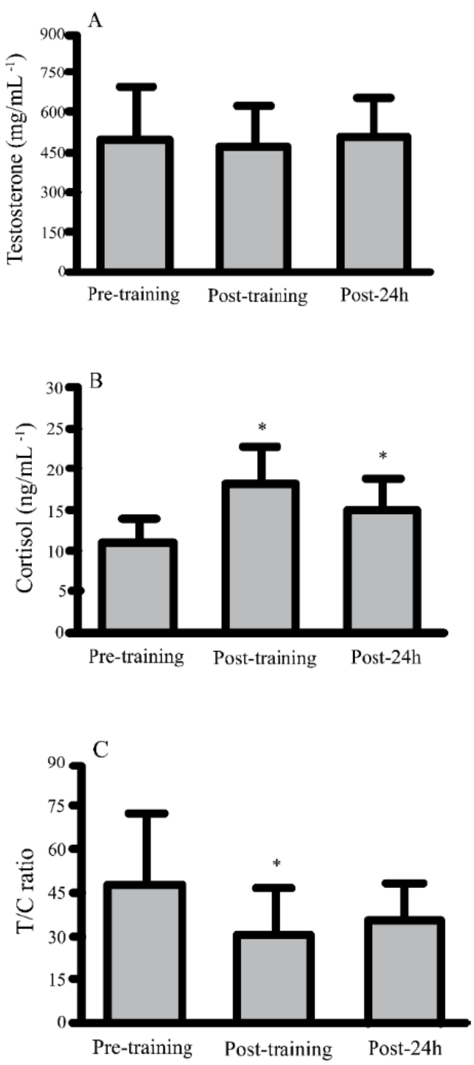

Figure 3. Hormonal concentrations (panel A: testosterone; panel B: cortisol; panel C: testosterone/cortisol ratio) before, after, and 24h after BJJ training.

Note: data expressed as mean and standard deviation; *different for pre-training values ($p<0.05$).

For cortisol concentrations, there was a time effect ($F_{2,26} = 12.2$; $p<0.001$), with higher values in post-training ($p<0.001$; d = 2.5, large) when compared to pre-training, and higher post-24h values when compared to pre-training values (p = 0.004; d = 1.3, large). Testosterone concentrations did not vary across measurements ($p>0.05$). For the testosterone/cortisol ratio, there was a time effect ($F_{2,26} = 5.9$; p = 0.008), with lower values for post-training when compared to pre-training values (p = 0.023; d = 1.12, large) (Figure 3, panel C).

For CK concentrations, there was a time effect ($F_{2,26} = 7.6$; p = 0.002), with higher values in post- (p = 0.016; d = 1.4, large) and post-24h training (p = 0.003; d = 1.7, large), when compared to pre-training values (Figure 4, panel A).

For AST concentrations, there was a time effect ($F_{2,26} = 18.4$; $p<0.001$), with higher values in post- ($p< 0.001$; d = 1.9, large) and post 24h training (p = 0.015; d = 0.95, moderate) as compared to pre-training values (Figure 4, panel B).

ALT concentrations differed across measurements ($F_{2,26} = 10.9$; $p<0.001$), with higher values in post- (p = 0.015; d = 0.9, moderate) and post 24h training ($p<0.001$; d = 0.9, moderate) as compared to pre-training values (Figure 4, panel C).

LDH differed across measurements, ($F_{2,26} = 18.1$; $p < 0.001$), with higher values in post- ($p < 0.001$; d = 1.3, large) as compared to pre-training values (Figure 4, panel D).

For RPE_{6-20}, there was a time effect ($F_{5,65} = 6.9$; $p<0.001$) between the different matches (first: 12 ±2 a.u.; second: 14 ±2 a.u.; third: 15 ±2 a.u.; fourth: 16 ±2 a.u.; fifth: 15 ±3 a.u. and sixth: 15 ±2 a.u.), with lower values for post-first when compared to post-third (d = 1.3, large), post-fourth (d = 1.4, large), post-fifth (d = 1.1, large), and post-sixth (d = 1.2, large) matches

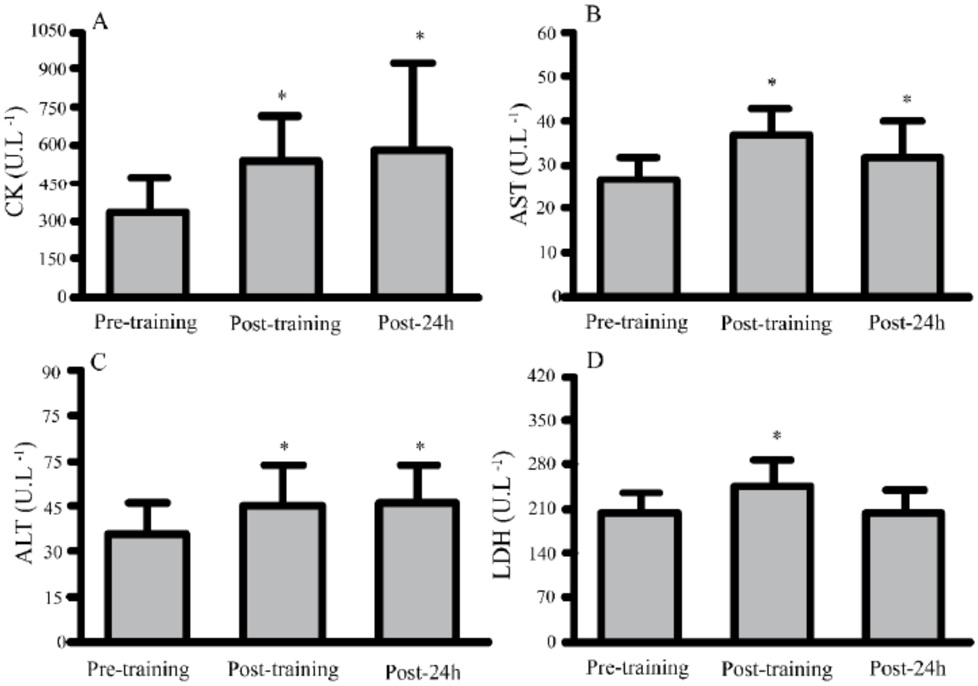

Figure 4. Cellular damage markers (panel A: CK; panel B: AST; panel C: ALT; panel D: LDH) before, after, and 24h after BJJ training.

Note: data expressed as mean and standard deviation; *different for pre-training values ($p<0.05$); **AST** aspartate aminotransferase; **ALT** alanine aminotransferase; **CK** creatine kinase; **LDH** lactate dehydrogenase.

($p<0.001$; for all comparisons). In the same way, lower values were found for post-second when compared to post-third (d = 1.1, large), post-fourth (d = 1.2, large), post-fifth (d = 0.8, moderate), and post-sixth (d = 0.9, moderate) matches ($p<0.001$; for all comparisons).

For RPR, there were differences observed between measurements: 9 ±1 a.u. for pre-training and 8 ±1 a.u. for post 24h training (t_{14} = 3.48; p = 0.004; d = −1.2, trivial), with higher values in pre-training as compared to post 24h. The RPE_{0-10} and ITL indicated by athletes were 8 ±2 a.u. and 733 ±136 a.u., respectively.

Significant correlations between La, HR and RPE_{6-20} were observed only during the post-fourth match, where La was observed correlations with HR (r = 0.48; $p<0.05$; moderate) and HR was observed correlations RPE_{6-20} (r = 0.66; $p<0.01$; large). A significant correlation between La and HR was observed during the post-fifth match (r = 0.81; $p<0.01$; very large), as well as during the post-sixth match (r = 0.48; $p<0.05$; moderate).

Significant correlations between ITL and ALT (Δ: post-training values minus pre-training values (r = 0.66; $p<0.01$; large); and Δ: post 24h values minus pre-training values (r = 0.77; $p<0.01$; very large) and LDH (Δ: post-training values minus pre-training values (r = 0.50; $p<0.01$; large); and Δ: post-24h values minus pre-training values (r = 0.59; $p<0.01$; large) were observed. No correlations were found between RPE_{0-10} or ITL and physiological responses (hormones and cellular damage) post-training, post-24h or deltas (post 24h measures minus post-training measures, or post-training measures minus pre-training measures) ($p>0.05$).

Figure 5 shows RPE with respect to an anatomical map.

Discussion

The study showed that cortisol levels increased after training and remained elevated until post-24h after training. Concentrations of CK, AST, ALT and LDH increased after training and also (except for LDH) remained high for up to 24 hours. RPE_{6-20} indicated that the intensity of training session as somewhat hard to hard. Significant correlations between La and HR and between RPE and HR were only observed after the fourth match. There were also correlations between ITL and delta of ALT (r = 0.66) and LDH (r = 0.50) after the training. This might lead one

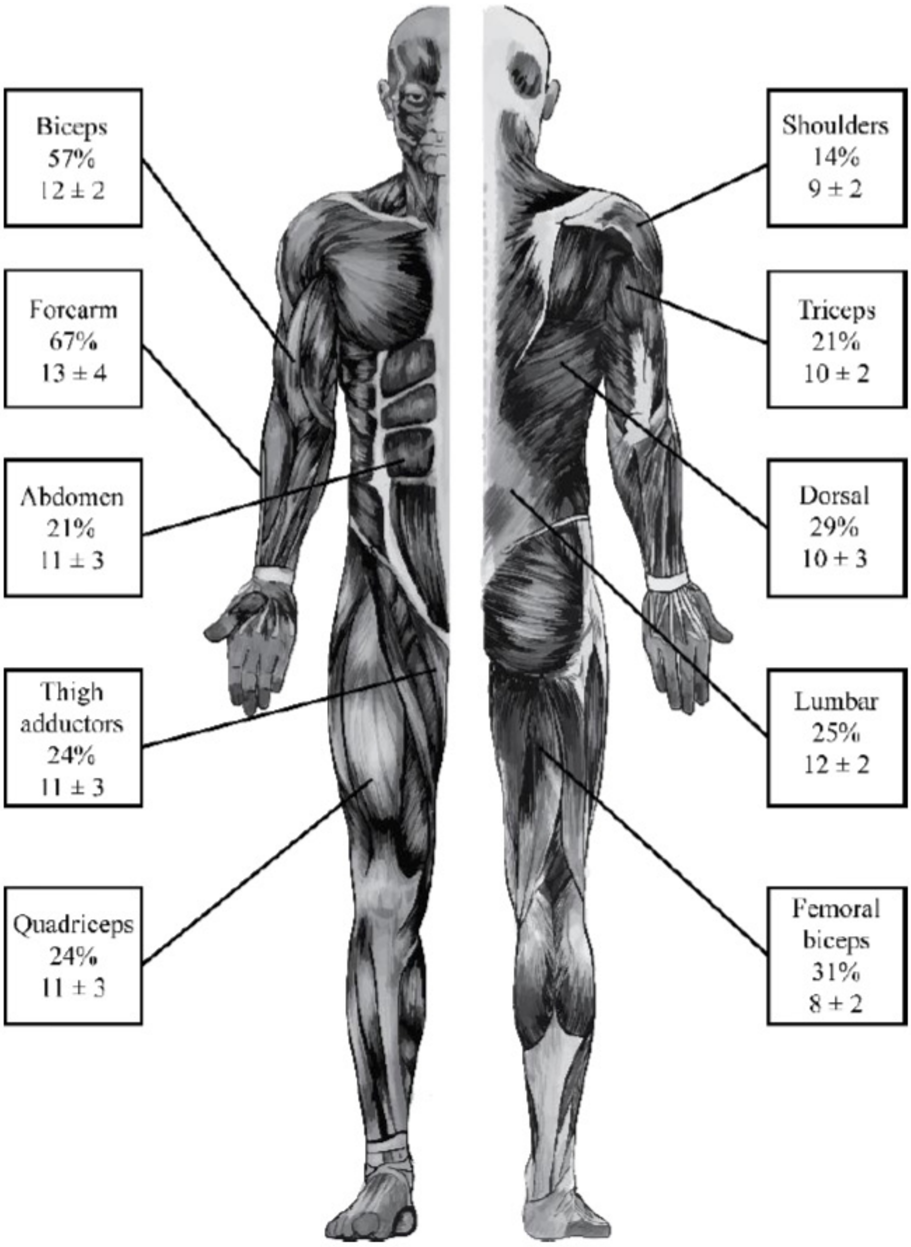

Figure 5. Rating of perceived exertion indicated by 14 athletes during the BJJ training (athletes participated in 6 matches each during an 84-match training session. Data expressed as mean, standard deviation and percentage; Borg-scale (6-20) was used).

to conclude that hormonal concentrations and cellular damage markers increased after training and remained high until post 24h. However, RPE_{6-20} was unable to predict the intensity of the glycolytic pathway and cardiovascular activation between matches. Moreover, no correlations were found between RPE_{0-10} or ITL and physiological responses (hormones and cellular damage either after training, post-24h or deltas (post-24h measurements minus post-training measurements, or post-training measurements minus pre-training measurements).

The purpose of sports training is to prepare athletes as far as possible for the exigencies of competition, since an organism tends to adapt per the stimulus it receives, specificity is a principle factor in training [11]. Training sessions should therefore mimic the demands of competition as closely as possible. Yet so far no study has verified whether or not the demands of training are equivalent to those of competition. It was noted above that, in the present study, La concentrations oscillated between ~8 and 12 mmol/L. These values are like those previously found in regional competitions between blue-belt athletes (6.2 ±2.3 mmol/L) [24] and between white- to brown-belt athletes (median and percentiles (25% and 75%): 10.1 (8.0 to 11.3) [4], as well as during the 2013 European championship between purple- and black-belt athletes (14.8 ±3.3) [25]. This is reasonable evidence on which to assume that the demands of training are in fact like those of competition.

An unfortunate feature in the design of this study was that all athletes, regardless of their graduations (blue, purple, brown and black belt), engaged in matches of equal length. A more ideal scenario would be one where the intensity of athletes' participation in training depends upon their graduation. For instance, match duration time could be determined according to graduation, for example 5 min for adult male white belts, 6 min for blue belts, 7 min for purple belts, 8 min for brown belts, and 10 min for black belts [5]. This grading of match times is likely to diminish the physiological and metabolic demand of matches on athletes with low belt grades, and heighten it for athletes of high belt grades [11]. Andreato et al. [26] analysed matches of varied duration (2 min, 5 min, 8 min, 10 min) and observed that, according to the classification proposed by Buccheit and Laursen [27], the rate of lactate accumulation was "strongly anaerobic" for 2 min and 5 min bouts, and "mildly anaerobic" for 8 min and 10 min bouts.

The present study demonstrated that a single training session can increase a BJJ athlete's catabolic status, given a reduction in the T/C ratio and an increase in cortisol levels. It also showed that a 24h rest period is insufficient to restore the anabolic/catabolic balance because cortisol levels remain high for at least 24h after training. Regarding hormonal responses, previous studies found that neither elicited alterations in cortisol and testosterone nor alterations in the cortisol/testosterone ratio were found in two consecutive simulated matches (two 10-min matches separated by 10min of rest) [28]. Andreato et al. [1] observed the same result for a simulated competition (four 10-min matches), though also found a decrease of epinephrine, norepinephrine and insulin, leading to a catabolic condition. Increases in salivary cortisol were observed by Moreira et al. [29] following three simulated matches that were 6 min in length. Their study was unique in that it compared salivary cortisol responses between simulated and actual competitions. They observed that actual competitions elicited higher cortisol concentration, indicating a greater stress condition (high activity of the sympathetic nervous system).

Evaluating the effect of a BJJ training session on cellular damage markers, Santos et al. [3] observed that the training session resulted in an increase in the markers used (CK and LDH). Moderate correlations were found between these markers (r = 0.59 and r = 0.48, respectively) and the athletes' perceived pain. Similar results were obtained by the present study, which found that all the markers used (CK, AST, ALT and LDH) remained high 24h after training had ended. Previous studies measuring cellular damage in response to BJJ matches have shown that these matches lead to damage of muscular tissue. The magnitude of this response tends to be greater after consecutive matches [1, 30] than after a single match [12, 26]. Match length also seems to influence the magnitude of this response: higher damage markers are present after matches of longer duration [26, 31].

Local perception is an instrument that can easily be used to measure an athlete's level of fatigue at specific points of the body. This kind of data is significant when developing prophylactic measures as well as prescribing muscular resistance training [17, 32]. In the present study, the main points of fatigue were the forearm and the biceps. These findings were similar to studies involving match simulations [2] and genuine competition [24], which demonstrated that the muscular groups most at risk of fatigue are those involved in "dispute and gripping", including those involved in gripping the opponent's *judogi* during a match. One of the goals of the present study was the rating of RPE and ITL to predict metabolic, damage, and hormonal responses. However, no correlation was found between these variables. This suggests the imprecision or fragility of subjective methods of measurement for regulating training loads [35][2] in BJJ sessions.

Previous studies have suggested that perceptive scales should be used with caution in combat sports, the reason being that athletes' perceptions of the intensity of their exertion during combat can easily be mistaken given that athletes are frequently distracted by extrinsic factors such as their opponent's actions, the judge's orders, or their coach's instructions [2, 13]. Future studies should therefore continue to evaluate the efficiency

2. Recommendation of the paper which is raising a lot of controversies concerning the terminology, the measurement and documenting of training load.

of perceptive scales as well as training control questionnaires (Daily Analysis of Life Demands in Athletes, or DALDA) [33] when dealing with longer training periods. Furthermore, non-invasive measures, such as heart rate variability, could also be tested in order to evaluate their reliability in monitoring the training of BJJ athletes [34]. In accordance with the present study's finding that the catabolic state remains high post-24h, as does the majority of cellular damage markers coaches should consider that a 24h recovery period may be insufficient for complete recovery after a typical training session. A longer period should be adopted for recovery and finishing.

Conclusions

This type of training increases the catabolic state and generates cell damage that fails to return to basal levels even post 24h. The study also found that RPE_{6-20} is not very effective for predicting intensity throughout the training (matches performed), which suggests that perceptive scales should be used with caution.

Competing interests

The authors declare that they have no competing interests.

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